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THE BOW OF THE DREADNOUGHT.

THE BATTLESHIP THAT REVOLUTIONIZED NAVAL WARFARE.

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THE DESIGN OF MODERN WARSHIPS

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MANY years ago a sketch design was prepared at the British Admiralty embodying the principal requirements then thought necessary in the "ideal" battleship, and the estimated cost of the vessel so projected was £1,800,000. The mere mention of such a sum at a time when the cost of the first-class battleships then being built did not much exceed £500,000 was deemed sufficient proof of the impossibility of combining in one vessel all the qualities desired. Now, however, such sums as those first mentioned do not appal, and most of the principal navies are being provided with battleships, each of which, when complete for sea, will cost in round figures about £2,000,000. This increase of cost has been, in the main, progressive, and has been principally brought about by the constantly-recurring demand for individual ships approximating ever nearer to the "ideal," such demand being stimulated by the continuous advances in shipbuilding and engineering science. This desire for more powerful battleships has resulted in a great increase of size, and whereas the *Majestic* class, built during the years 1896-9, are 390 feet long, 75 feet broad, and have a normal, or navy list, displacement of 14,900 tons, the *St. Vincent*, the latest of the *Dreadnought* type now under construction, is 110 feet longer, 9 feet wider, and has a normal displacement of 19,250 tons, whilst in the United States and Japan vessels of still greater normal displacement are being built or contemplated. The increase of size is still more strongly emphasized by comparing the *deep*-load displacements; that of the *Majestic* class is about 16,000 tons, whilst the corresponding figures for *Dreadnought* and the United States battleship *Delaware* are 22,200 tons and 22,440 tons, respectively. This tendency to increase is not peculiar to warships, but is equally marked in vessels for the mercantile marine, and the displacements just given for the latest battleships appear small when compared with the 38,000 tons of the Cunard Company's vessels *Mauretania* and *Lusitania*. It is the object of the present article to trace in some detail the growth of battleships since the publication of the preceding marine number of this magazine and to pass in review some of the principles underlying their design, but before doing so a brief outline will be given of some of the great developments which have taken place in important factors affecting warship design and in some of the types of war vessels of

lesser, although of considerable, importance.

Amongst the outstanding features affecting design must be placed the introduction of the steam turbine, and its marvelously rapid adoption is evidenced by the fact that, whereas in the year 1900 there was only one war vessel, the torpedo boat destroyer *Viper,* fitted with the Parsons turbine, at the present time every warship for the British navy is designed to have propelling apparatus of the type just named. The combined horse-power of those vessels is 354,000, whilst that of completed ships in which the same type of machinery is installed is 440,000, so that for the British navy alone turbines representing about 800,000 horse-power have been built or are under construction. Other countries, too, including France, Germany, Russia and the United States, have, installed or under construction, Parsons turbines to the extent of 530,000 horse-power. The rapid adoption of the steam turbine was undoubtedly due to some extent to the results of the careful comparative trials carried out by the British Admiralty with two third-class cruisers, the *Topaze* and *Amethyst,* of identical size and shape, and differing only in the type of propelling apparatus. The former is fitted wtih twin-screw reciprocating engines, whilst the latter has three screw shafts and Parsons turbines. Trials proved that with the same total expenditure of coal and number of pounds of steam used, the turbine-driven vessel had a speed nearly 1½ knots in excess of the *Topaze.* This result, confirming others obtained in the mercantile marine, must have been one of the main factors considered by the Admiralty before reaching their decision to adopt turbines in all future vessels. The reasons for installing turbines in the *Dreadnought* are given in the Admiralty memorandum as follows: "Whilst recognizing that the steam-turbine system of propulsion has at present some disadvantages, yet it was determined to adopt it because of the saving in weight and reduction in number of working parts, and reduced liability to breakdown; its smooth working, ease of manipulation, saving in coal consumption at high powers and hence boiler-room space, and saving in engine-room complement; and also because of the increased protection which is provided for with this system, due to the engines being lower in the ship; advantages which much more than counterbalance the disadvantages." Other types of steam turbine, such as the Curtis, are being adopted in the United States and elsewhere.

Another factor influencing British warship design has been the introduction of oil fuel, either as an auxiliary to coal, as in battleships and large cruisers, or as the sole source of power. The "Coastal" and later types of destroyer have boilers designed to burn oil only, and to this fact may be attributed in no small degree the great success of these types. It is understood, however, that the British destroyers of the 1908-9 programme are to have boilers fitted for burning coal only.

Modern propellants, too, have been responsible for modifications in design. Although such propellants have ballistic properties greatly superior to those of earlier date, they are also less stable, and their instability is greatly increased with increase of temperature. Their adoption also occurred at a period marked by great increases in the boiler installations of vessels and in the size and number of auxiliary machines, all sources of heat. Thus it has been increasingly difficult to find satisfactory locations for the magazines, and special measures must be adopted in order to keep such spaces cool. In some French and Russian vessels the magazines have been ventilated by cooled air, and quite recently cooling apparatus has been introduced into British vessels, at a total cost of £500,000, having the same object in view. That the danger from deterioration is real

H. M. S. LORD NELSON

was abundantly demonstrated by the calamitous explosions in the magazines of the Japanese battleship *Mikasa* and the French battleship *Iéna,* the explosion in each case being attributed to spontaneous ignition of powder. The increased ballistic properties of modern propellants, too, have rendered additional hull stiffening necessary in way of gun positions.

It is only further necessary to instance the great development of fire control from stations on the mast at least 100 feet above water, with their Barr and Stroud range-finding apparatus and transmitting and receiving fire-control instruments; the installation of wireless telegraphy; the adoption of high-tensile steel for particular parts of large vessels and of special high-tensile steel for destroyers and similar craft, and the great improvements in armament and armour, which will be more particularly alluded to later, to drive home the conviction that in warship designing, at any rate, "there is no standing still."

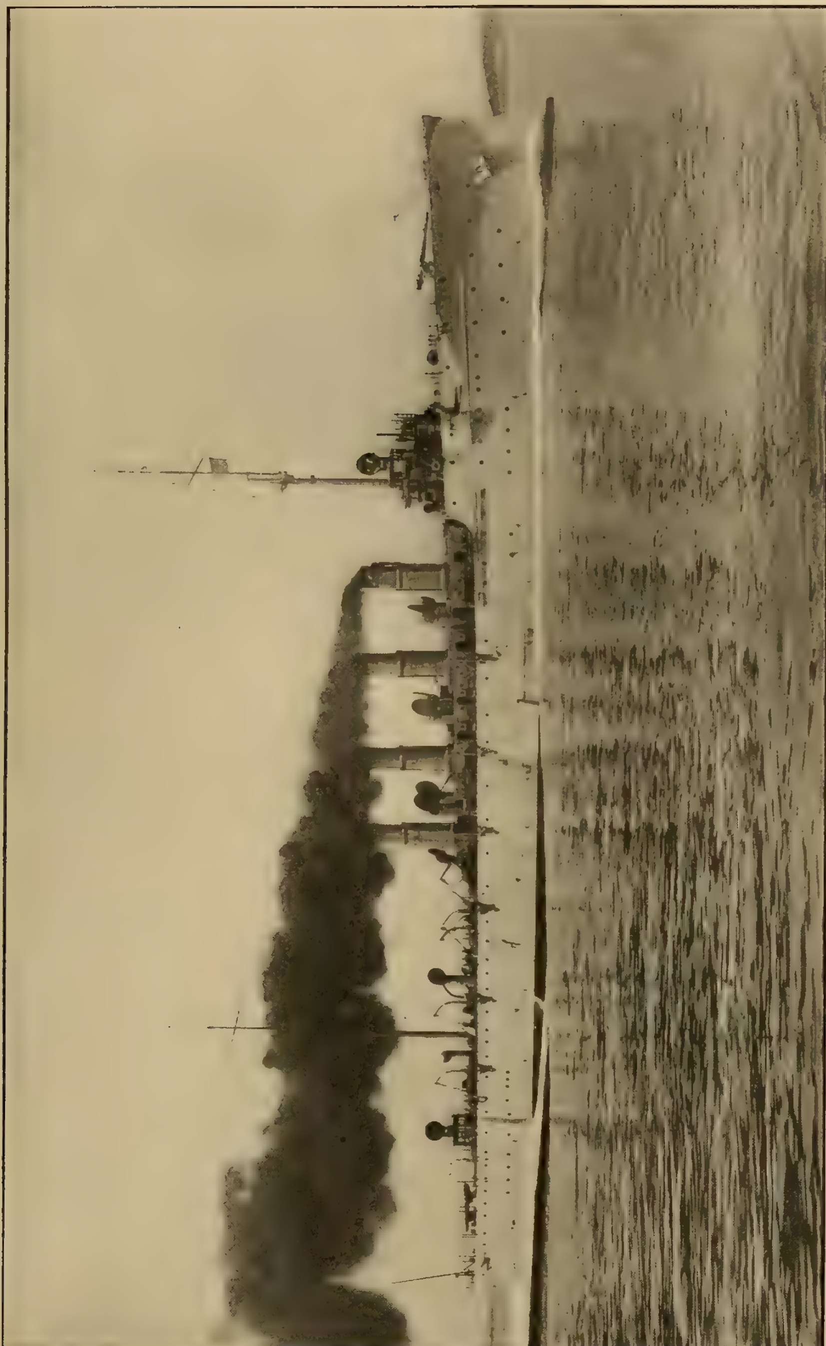
As to developments within certain types during the last decade, the progress of the torpedo boat destroyer can be gauged from the fact that in 1898 the typical vessel was of about 370 tons displacement and 30 knots speed, using coal as fuel and having reciprocating engines driving twin screws, whereas now most of the vessels of the *Cossack* type, of about 900 tons displacement, are in service, having distinctly exceeded their contract speed of 33 knots; they burn oil fuel only, and their three screw shafts are driven by turbines. A still larger vessel, the *Swift,* a special-type turbine-driven destroyer of about 1,800 tons displacement, has been designed with the very high speed of 36 knots. The German destroyer *G.* 137, of 570 tons displacement and fitted with Parsons turbines, has a speed of over 32 knots, whilst the latest of the type designed for the United States are to have the type of propelling apparatus just mentioned, a normal displacement of 700 tons and a speed of 28 knots, using coal only as fuel.

Even the slightest historical sketch of the foregoing type should include some reference to the valuable work done by the committee on torpedo-

boat destroyers appointed by the Admiralty. The main conclusions arrived at by this committee were afterwards embodied in a paper read by Professor J. H. Biles, one of its members, before the Institution of Naval Architects in 1905. One of the earlier destroyers (the *Wolf*) was lent by the Admiralty for experiment, and exhaustive tests were carried out, both in dock and at sea in rough water, to ascertain the adequacy or otherwise of the structural arrangements adopted in that type of vessel. The actual stresses to which certain portions of the structure were subjected during experiments were ascertained by the use of Stromeyer's strain indicators and compared with those calculated in the usual way. It was found that the usual method of calculating the longitudinal stresses produced in the structure when subjected to *known* bending moments gave results closely in agreement with those ascertained by experiment. Further, that the stresses brought upon the vessel when in a rough sea and amongst waves of about her own length were distinctly less than given by calculations based upon the usual assumptions, indicating that, so far, at any rate, as destroyers are concerned, the theoretical method of procedure errs on the safe side.

Amongst new types of warships which have appeared within the last ten years or so, the armoured cruiser takes a foremost place, and the advance made in the type will be evident by comparing the *Cressy*, completed in 1901, with the *Invincible* class, now completing. The former, 440 feet long, 69½ feet wide, has a displacement of 12,000 tons and a speed of 21½ knots; her armament consists of two 9.2-inch, twelve 6-inch, and fourteen 12-pounder guns, and the maximum thickness of her water-line Krupp armour is 6 inches. On the other hand, the *Invincible* class are 530 feet long, 78½ feet wide, and have a displacement of 17,250 tons and a speed of 25 knots; they carry eight 12-inch and twenty "anti-torpedo" guns, and the water-line armour has a maximum thickness of 7 inches. In Germany a large armoured cruiser of about 17,000 tons displacement has been laid down, to have a speed of 25 knots and to carry ten or twelve 11-inch guns. The most recent United States representative vessels of this type are the *Tennessee* class, whilst in France the *Edgar-Quinet* and *Waldeck-Rousseau,* sister ships, are under construction. The first-named class are 502 feet long, nearly 73 feet wide, and displace 14,500 tons; they carry four 10-inch, sixteen 6-inch, and twenty-two 14-pounder guns, and

H. M. S. PATHFINDER



UNITED STATES CRUISER SALEM, FITTED WITH CURTIS TURBINES, SPEED 25.95 KNOTS

LAUNCH OF THE BRAZILIAN BATTLESHIP MINAS GERAES. SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

have 5-inch armour protection at the water line; one of the latest, the *North Carolina,* attained on trial a speed of 22.48 knots. The *Edgar-Quinet* is 515 feet long and 70¼ feet wide, and has a displacement of 13,780 tons; the armament comprises fourteen 7.6-inch and sixteen 9-pounder guns; the water-line belt has a maximum thickness of 6½ inches, and the designed speed is 23 knots. It will be evident that the largest vessels mentioned have many of the attributes of battleships, and are well described by the term "cruiser-battleships," sometimes applied to them.

Concurrently with the re-introduction of the armoured cruiser, the building of large *protected* cruisers, such as the British *Powerful* and *Terrible,* ceased. Smaller protected cruisers of a special *Scout* class have, however, been introduced, the pioneers being the British *Pathfinder* and seven other very similar vessels, all of about 3,000 tons displacement and 25 knots speed. Of the same class are the somewhat larger United States scout-cruisers *Birmingham, Chester,* and *Salem,* designed for 24 knots; the second of these, fitted with Parsons turbines, maintained for four hours a speed of 26½ knots, whilst the *Salem,* fitted with Curtis turbines, attained a speed of 25.95 knots with 19,200 brake-horse-power. The new German third-class cruisers *Pfeil* and sisters displace 3,800 tons, and have a designed speed of 24½ knots.

Another type, too, which has received much attention of recent years is the submarine vessel, and has shared the inevitable fate of growth, those now under construction for the British navy having a displacement nearly three times that of the earliest vessels, whilst the horse-power has increased in an even greater proportion.

All the types of warships just mentioned, with some others which need not be named, find a place in modern

navies and have important duties to fulfil, but it has been abundantly demonstrated during naval wars—and at no time more conclusively than by those of recent date—that it is upon its battleships a navy must rely to obtain and keep command of the sea. The pages following will therefore be devoted to an examination of the later steps by which the heavily-armed and armoured vessel has reached its present stage of development, and to a statement of the principles underlying its design and construction.

It is an axiom that a battleship design should be *well-balanced;* that is to say, features should not be abnormally developed at the expense of definite offensive or defensive qualities; and powers of defense should not be disproportioned to those of offense. For example, of two vessels of the same displacement and gun armament, the element of speed might be given such prominence in one as to leave little or no weight available for armour protection; or, to take another illustration, the necessity of having a large area of exposed side covered with non-perforable armour may be so insisted on as to render unavoidable a great weakening of the offensive powers. In each case there would be evident failure to realize the best all-round design possible. A battleship should have such a form and dimensions as shall ensure good seagoing qualities, providing a steady gun platform in heavy weather and ability to maintain a high speed at sea. Such a ship should also have a large radius of action—secured by ample fuel supply in association with economical fuel-burning and steam-using apparatus—and ample structural strength, not only under normal circumstances, but after damage in action: and must also carry a heavy gun armament well protected by armour, and be provided with armour for the protection of machinery and other "vital" parts, as well as for the defense of buoyancy and stability. Regarding the balance of offensive and defensive qualities, a well-known warship designer has stated: "There should be

LAUNCH OF THE U. S. BATTLESHIP SOUTH CAROLINA AT THE YARDS OF THE CRAMP SHIPBUILDING COMPANY, PHILADELPHIA

the greatest offensive power, and the defensive arrangements should be such as to ensure the ship, as far as possible, and in equal degrees, against all the various modes in which she may be disabled or destroyed. From this it will follow that it should not be in the power of the enemy to disable the ship by one single blow delivered by any means at his command, if this could have been prevented by causing other defenses, where he has not this power, to surrender a portion of their strength to succour the weak part." There is, however, no certain means of determining the relative likelihood of damage from the several modes of attack, and there is consequently room for difference of judgment, based, as that judgment must be to a great extent, upon the oft-times conflicting reports of the results obtained in naval battles, on peace evolutions, special experiments, and target practice. The opinion formed at different periods by the responsible advisers of several important governments as to the best balance between competing qualities can be gathered from the accompanying diagrams and following tabulated particulars:

TABLE I.

Name of Vessel.	Nationality.	Approximate Date of Completion.	Gun Armament.*
Class.			
Majestic	British	1896–9	4—12″, 12—6″, 16—12-pounders.
Iowa	U. S. A.	1897	4—12″, 8—8″, 4—4″, 22—6-pounders.
Bouvet	French	1898	2—12″, 2—10.8″, 8—5.5″, 8—4″.
Shikishima	Japanese	1900	4—12″, 14—6″, 20—12-pounders.
King Edward VII	British	1904	4—12″, 4—9.2″, 10—6″, 14—12-pounders.
Connecticut	U. S. A.	1906	4—12″, 8—8″, 12—7″, 20—12-pounders.
Dreadnought	British	1906	10—12″, 27—12-pounders (3″).
Deutschland	German	1906	4—11″, 14—6.7″, 22—3.4″.
†*Agamemnon*	British	1908	4—12″, 10—9.2″, 15—12-pounders.
Aki	Japanese	1908	4—12″, 12—10″, 12—4.7″.
South Carolina	U. S. A.	Building	8—12″, 22—14-pounders (3″).
Delaware	U. S. A.	Commencing	10—12″, 14—5″.
Danton	French	Building	4—12″, 12—9.4″, 16—12-pounders.
St. Vincent	British	Building	10—12″ and a number of special anti-torpedo guns.
Baden (new)	German	Building	12—11″, 12—6.8″ and other smaller guns (uncertain).

* Excluding small guns below 6-pounders. † Design preceded that of *Dreadnought*.

TABLE II.

Class.	Length.	Breadth.	Normal Displacement (Tons).	*Speed in Knots.	I. H. P.	Maximum Thickness of Belt Armour at Waterline (Inches).
Majestic	390′	75′	14 900	17½	12,000	9″ (Harveyed steel).
Iowa	360′	72¼′	11,346	17.09	11,933	14″ (Harveyed steel).
Bouvet	401′	70¼′	12,000	18.2	14,000	15¾″ H. S.
Shikishima	400′	75¼′	14,850	18.3	16,355	9″ K. S.
King Edward VII	425′	78′	16,350	19	18,100	9″ K. S.
Connecticut	450′	76¾′	16,000	18¾	16,500	11″ K. S.
Dreadnought	490′	82′	17,900	21¼	24,700	11″ K. S.
Deutschland	398′	72¾′	13,200	18½	16,950	9½″ K. S.
Agamemnon	410′	79½′	16,500	18¾	17,285	12″ K. S.
Aki	492′	83½′	19,800	20	21,600	9″ K. S.
South Carolina	450′	80¼′	16,000	18½	16,500	10¼″ K. S. (11¼″ in way of magazines).
Delaware	510′	85¼′	20,000	21	25,000	11″ K. S.
Danton	475¾′	84′	18,400	19	22,500	10″ K. S.
St. Vincent	500′	84′	19,250	21	24,500	Not known.
Baden (new)	472′	82¾′	18,307	19½	25,000	12″ K. S.

* Trial speeds where known, otherwise designed speed given.

The most cursory glance at the tables given above will suffice to show that within the last few years the responsible authorities have called for great advances in speed and offensive and defensive powers, and these subjects will now receive some detailed attention in the order named.

Ten years ago the accepted speed for battleships was 17 to 17½ knots, and was gradually raised in succeeding years until, just before the ad-

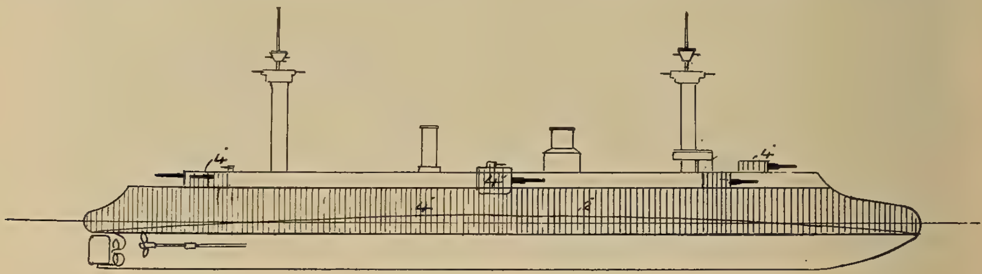
vent of the *Dreadnought,* the accepted speeds ranged from 18 to 19 knots. At the trials of the vessel named, however, in October, 1906, 21¼ knots was obtained during a run of eight hours, and the United States vessels *Delaware* and *North Dakota* are also designed for 21 knots. The high speed of *Dreadnought* has been obtained by installing machinery of 50 per cent. greater power than in immediately preceding vessels and using Parsons turbines in association with four shafts and screws. The *Delaware* will have reciprocating engines and twin screws, whilst the *North Dakota* will have twin-screw turbines, Curtis type. The reasons for adopting the high speed given to *Dreadnought* were stated in the official memorandum relating to that vessel. It is said: "Mobility of forces is a prime necessity in war. The greater the mobility the greater the chance of obtaining a strategic advantage. This mobility is represented by speed and fuel-endurance. Superior speed also gives the power of choosing the range. To gain this advantage, the speed designed for the *Dreadnought* is 21 knots." The fuel endurance of this vessel is very large, the coal-bunker capacity being at least 2,700 tons, whilst a considerable quantity of oil fuel can be carried in addition. Other things remaining the same, increase of speed involves increase of length, and therefore of freeboard, particularly forward, in order that the seagoing qualities may remain unimpaired. The great step in speed recently taken is no greater than has occurred at previous periods in the history of warship design; the *Admiral* class, for example, had speeds of about 16½ knots, as compared with the 14 knots of the immediately preceding vessels. In this case, however, the change was accompanied with such modifications of armament, armour, and dimensions that the ships were of less displacement and cost than the somewhat earlier *Inflexible*. Many distinguished naval officers warmly advocate the recent advance to 21 knots speed, whilst others doubt the wisdom of so materially increasing the speed at the expense of other qualities, or of great increase in cost: in

FRENCH BATTLESHIP REPUBLIQUE IN THE DOCKYARD AT BREST

the opinion of these latter the possession of an extra two knots speed does not confer material strategic advantages, whilst its value from a tactical point of view is even less, and argue that the weight and cost involved in increase of speed could have been better utilized by augmenting the offensive or defensive powers. On this point Admiral Sir Cyprian Bridge has said that conclusions should not hastily be drawn concerning speed, as it is only one of the various elements of fighting efficiency; that a ship of war is intended primarily to fight, and not to run away, and that care should be taken not to give to any other element undue prominence over the element of offensive power in the design of a ship meant to be capable of destroying or defeating her antagonist. It is understood that in the latest German designs the speed aimed at is 19½ knots, and that contemplated for new French and Japanese vessels 20 knots. High speeds call for long ships, and such are likely to be less handy than shorter vessels; the adoption of large rudder areas and good "cut-up" of keel, particularly aft, reduces this disadvantage to a minimum.

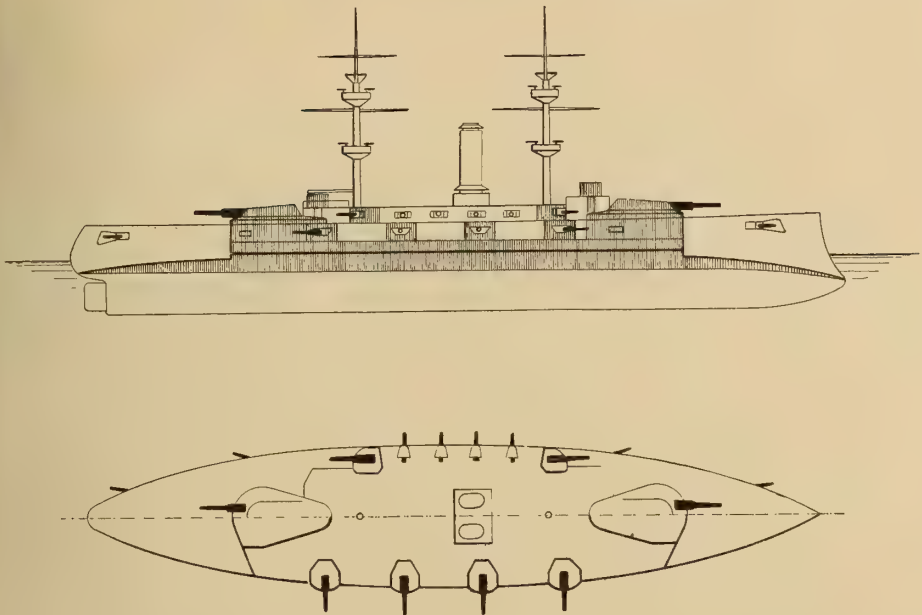
H. M. S. INFLEXIBLE (1881)

Turning now to offensive power, the calibre of the largest gun installed on battleships has remained the same throughout the period under consideration, but the guns of latest type are heavier and much more powerful than those of earlier design, the longer length and greater chamber capacity adopted conducing to much greater muzzle energy and increased perforating power: whilst with improved mounts and apparatus for handling ammunition, much greater rapidity of fire than could be obtained a few years ago is now possible. The soft iron cap adopted in recent years on the point of the projectile has increased the power of the gun against hard-faced armour.



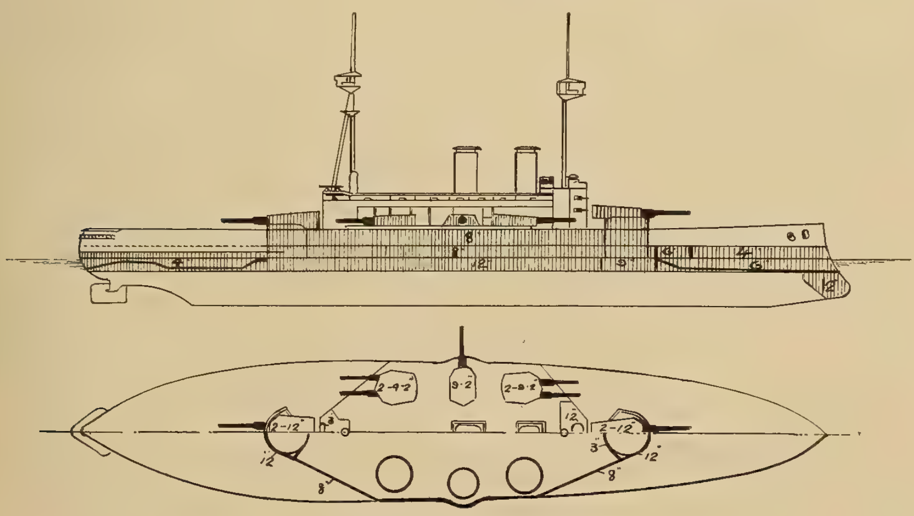
FRENCH CRUISER DUPUY DE LOME

A reference to Table I. will show that the total gun-power of battleships has been considerably increased of late years, particularly as regards its secondary armament. In the *Devastation* of 1873 and *Dreadnought* of 1875 all the guns were of the same calibre except some small quick-firers, and in the *Inflexible,* which followed, the guns next in size to the 80-ton turret guns were of 4-inch calibre only. With the advent of the *Admiral* class, however, there was introduced a secondary armament of six 6-inch guns, and in later vessels such armament was still further de-

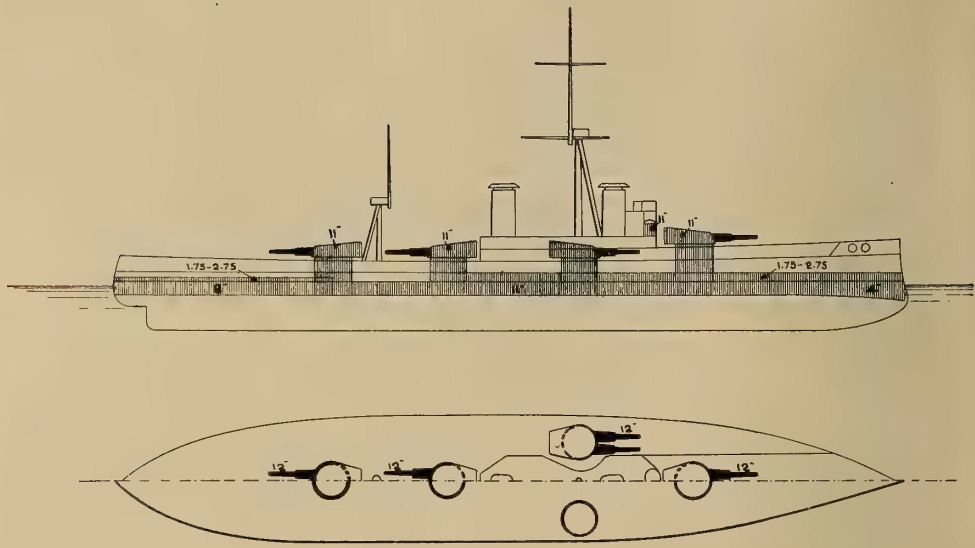


H. M. S. MAJESTIC

veloped, so that at the time of the *Majestic* the primary armament consisted of four 12-inch guns, the secondary armament of twelve 6-inch, quick-firing guns on central-pivot mountings, and the tertiary armament of sixteen 12-pounders. In still later vessels, augmentation of gun power was obtained by introducing guns of calibre intermediate between the 12-inch and 6-inch types, until (confining attention for the moment to British vessels) in the *Lord Nelson* and *Agamemnon* no 6-inch guns were installed, the secondary armament consisting of ten 9.2-inch guns. In



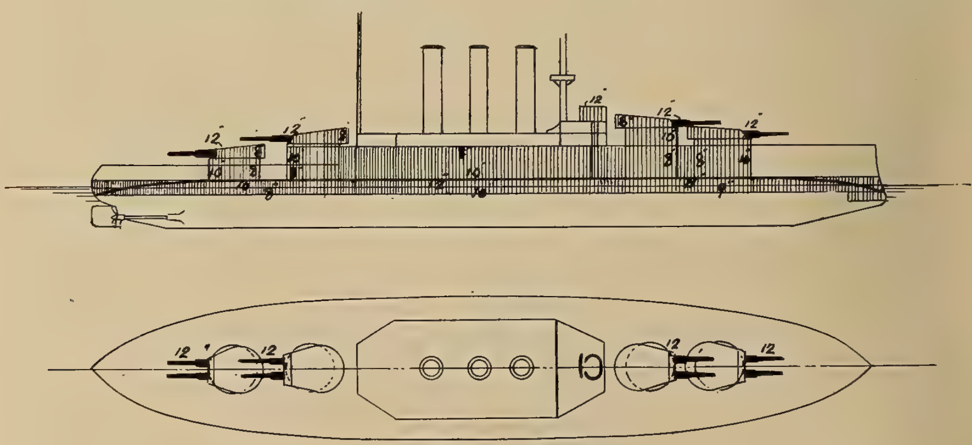
H. M. S. LORD NELSON



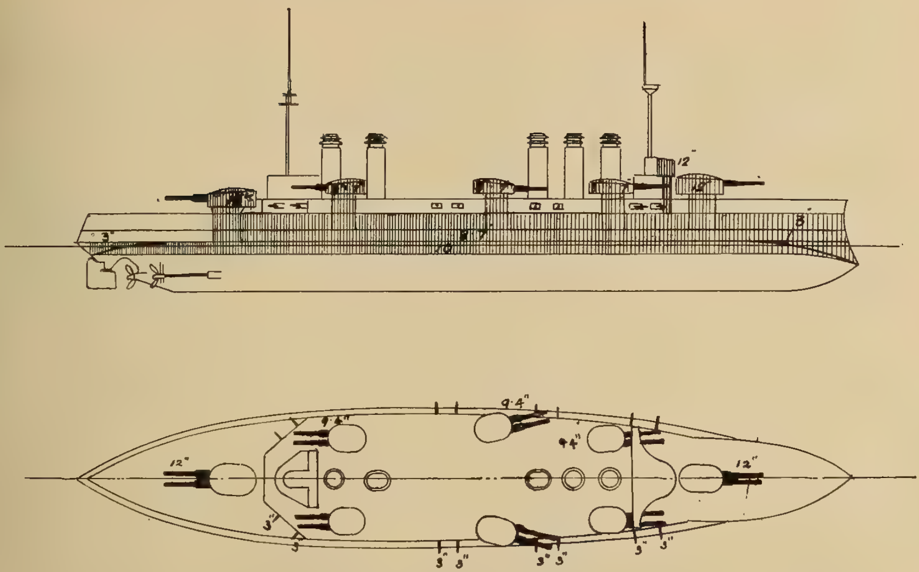
H. M. S. DREADNOUGHT

the 1906 *Dreadnought* a still further development took place, and all the big guns were made of the same calibre; a numerous battery of 3-inch "anti-torpedo" guns was introduced, and the usual intermediate or secondary battery was suppressed Thus was re-introduced the "single-calibre heavy-gun ship" which has marked a distinct era in battleship design, and which has provoked much discussion, as well as emulation. The United States navy has a similar type in the *South Carolina* and *Michigan*. In view of these developments, it is interesting to remember that so long ago as 1868 Vice-Admiral E. P. Halsted proposed a "first-rate," 455 feet long, and having a displacement of 14,350 tons, to carry fourteen 9-inch guns in *seven* turrets, the pair at each end being *en echelon*, and the other three disposed on the middle line. The center of guns was to be 18½ feet above water.

The arguments in favour of the single-calibre, heavy-gun type are: 1. As each calibre gun should have a



U. S. BATTLESHIP SOUTH CAROLINA

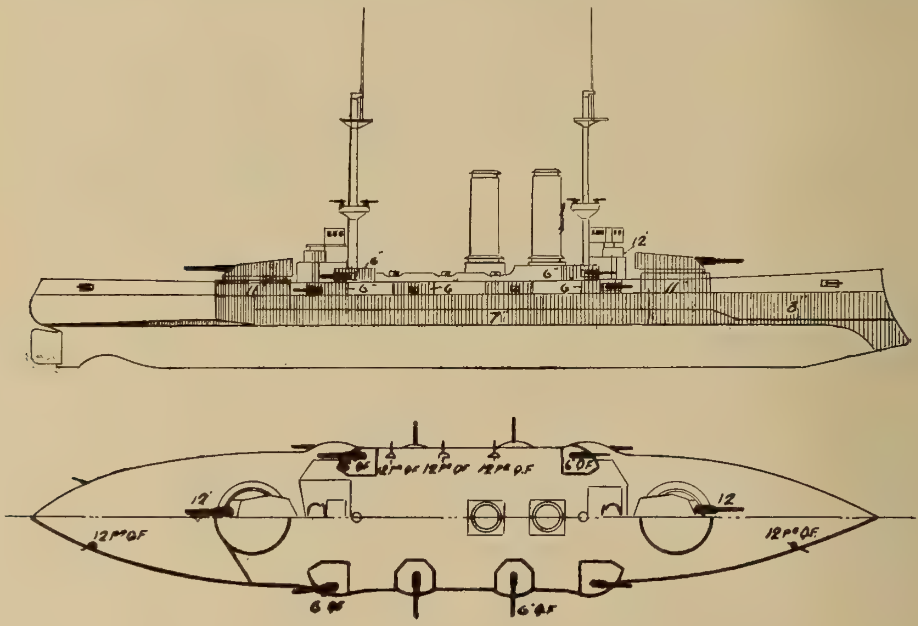


FRENCH BATTLESHIP DANTON

separate fire-control party, these arrangements are simplified by the adoption of a uniform calibre. 2. Intense concentration of fire is possible with ships carrying a large number of the heaviest guns. 3. For the ranges at which battles are likely to be fought in future, large guns will deliver much more powerful blows, and the percentage of hits at such ranges is greater with large than with medium-calibre guns. On the other hand, it is urged that even at long ranges medium shells with heavy bursting charges are effective against the unarmoured portion of the upper works of an enemy, and can thus seriously affect his stability and manœuvring powers, as will be pointed out later on. Also that the rapid destruction of upper works would greatly impede communications, and the smoke from damaged funnels, finding its way through ventilators, etc., into the interior of the vessel, would seriously impair its working efficiency. That there is a difference of opinion on this subject will be evident from the fact that the one-calibre principle has not been adopted in all countries; France, for example, has in the *Danton* a mixed armament, and proposes to fit six 12-inch, eight 9.4-inch and eighteen 3.9-inch guns in the 20,000-ton battleships to be laid down in the years 1909 and 1910. Japan also, in her latest designs, has adopted a secondary armament of 6-inch guns, supplemented, according to some accounts, by others of 4.7-inch calibre. In the most recent vessels of one-calibre type the strength of the "anti-torpedo" armament has been greatly increased. Thus 5-inch guns are to be fitted to the *Delaware*, and it is currently reported that the similar armament of *St. Vincent* will consist either of 4-inch or 4.7-inch guns.

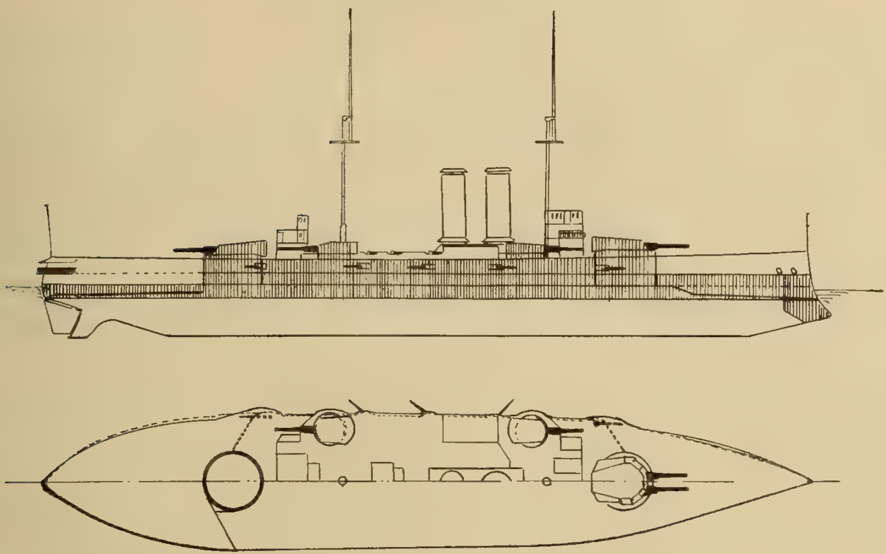
Distinct modifications in the method of protecting the guns, particularly as regards secondary armaments, have taken place during the last ten years, with consequent modifications in their arrangement. It is generally desirable to spread the guns on a ship as much as possible, so as to minimize the damage that can be done by a single shot from the enemy, whilst at the same time providing for the easy concentration of their fire when desired. It is also necessary that guns should

have sufficient "command," or height above water, to enable them to be effectively used in the heaviest weather in which naval actions are likely to be fought. With the longer guns now in use more command is necessary than before for the lower guns of secondary armament. Referring specially to British ships, the primary armament down to and including the *Lord Nelson* class was however, having four 9.2-inch guns in turrets above the upper deck as the most important guns of secondary armament, the 6-inch guns were arranged in a single box-battery above the main deck, as in the earlier Japanese vessel *Mikasa*. The 7-inch guns of the *Connecticut* class are also disposed in a similar manner, the eight 8-inch guns being in four turrets above the upper deck. In these



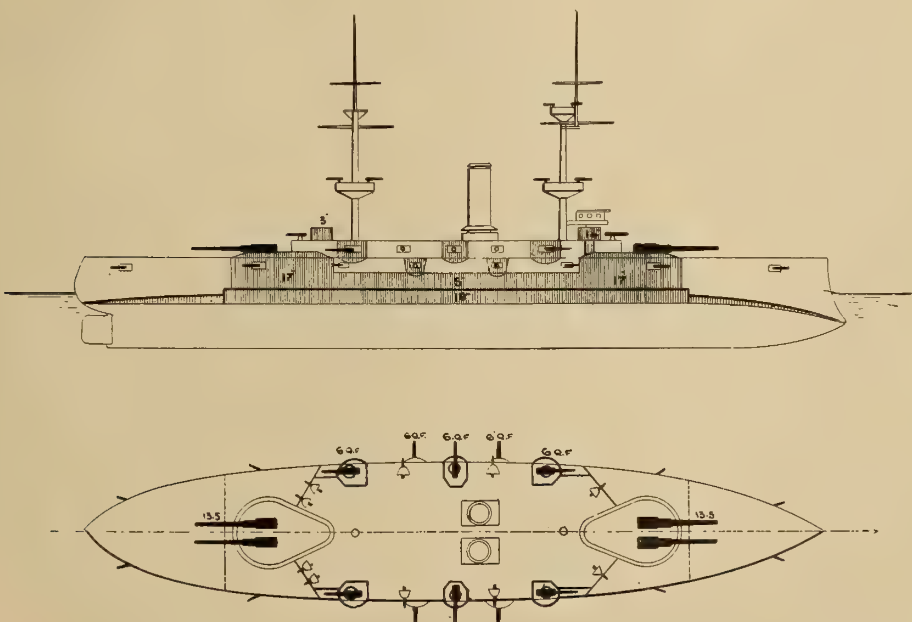
H. M. S. EXMOUTH

disposed in two gun-houses or turrets in strongly-fortified positions on the middle line of ship, one forward and one aft, the gun houses of later ships being much more heavily armoured than those of earlier design. In later vessels, viz., those of the *Dreadnought* class, the ten 12-inch guns have been placed in five gun houses. As to secondary armaments, in the *Majestic* each gun was placed in a separate casemate, as in the earlier *Royal Sovereign* type, for protection against quick-firing guns; and the same arrangement was adopted for the similar guns in the *Canopus, Formidable* and *Exmouth* classes. In the *King Edward VII.*, cases isolation of 6-inch guns is obtained by working longitudinal splinter bulkheads of nickel steel 1½ inches to 2 inches thick in these batteries, in association with transverse bulkheads of similar thickness between each pair of guns. The *Lord Nelson* marks a further step, all the guns of secondary armament being of 9.2-inch calibre, placed in turrets above the upper deck, an arrangement ensuring greater command than was possible for the earlier 6-inch guns on main decks. This question of height of gun axes above water has always received attention, and the minimum command is dependent upon the freeboard judged to be re-

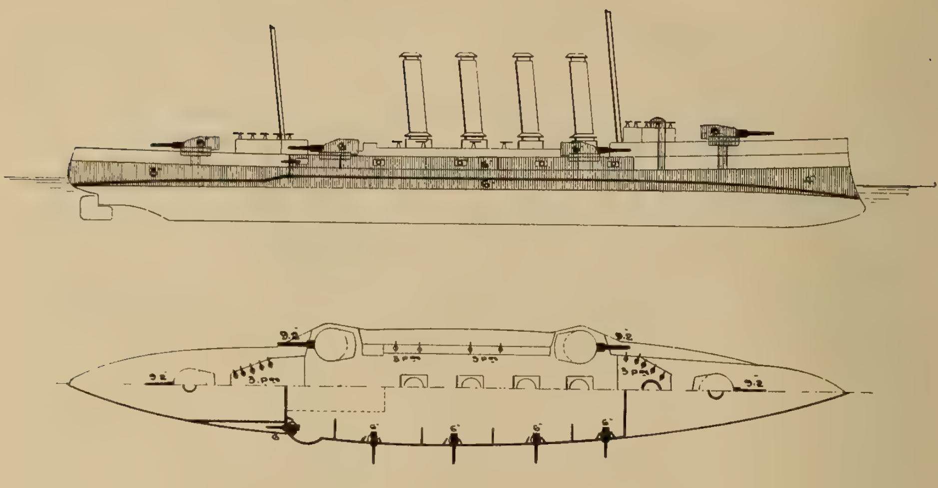


H. M. S. KING EDWARD VII.

quisite from sea-going considerations. Thus the *Admiral* class had greater freeboard and "command" than the low-freeboard *Inflexible,* whilst the *Royal Sovereign* type was again distinctly superior in these respects to the *Admirals.* With the higher freeboard desirable—especially forward—for the long battleships of recent design, where a forecastle has been introduced, the command of forward guns has again been greatly increased, so that instead of the 23 feet of *Royal Sovereign,* the highest guns



H. M. S. ROYAL SOVEREIGN



H. M. S. DUKE OF EDINBURGH

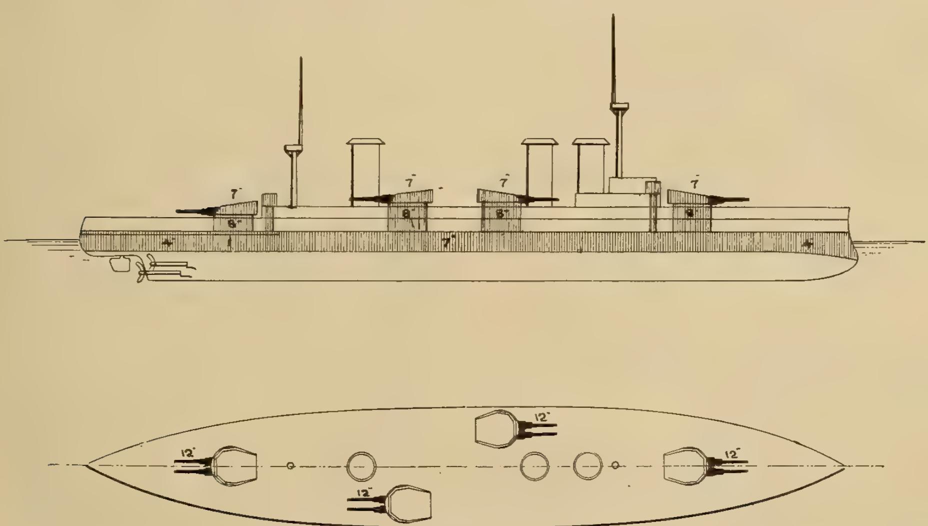
of the *Dreadnought* and *South Carolina* are about 33½ feet above water, and those of *Delaware* about 39½ feet. The French have consistently adopted relatively high gun command, that of their highest guns being often as much as from 7 to 10 feet greater than in contemporary designs elsewhere; in the *Liberté,* for example, the height of forward turret guns is 33½ feet, as compared with 26½ feet in *Connecticut* and about 24 feet in *King Edward VII.* This was characteristic even at the close of the eighteenth century, for one of the improvements then effected in British vessels was to raise the lowest tier of guns in imitation of the French, as it was found that when engaging an enemy to leeward they were obliged, on account of crankness of vessel and lowness of battery, to keep the lower ports closed; whereas French ships, being comparatively stiff, and having the lower guns well above water, could attack with all their weapons. Too great command, however, is undesirable, since the higher the guns the greater will be their motion in a seaway, and the greater therefore will be the difficulty of aiming: and the increased height involves additional weight of armour for protection, and a relatively higher position of center of gravity of vessel, this being detrimental to stability when ship is in damaged condition. Moreover, war experience has shown that the higher a gun is the greater is its liability to be hit, so that command beyond what is necessary to ensure the use of guns in any weather in which actions are likely to be fought is objectionable.

In arranging guns on board, care should be taken to ensure the provision of the largest possible horizontal arcs of fire; this can be best obtained by the use of turrets, and, as experience in fleet actions during the Spanish-American and Russo-Japanese wars indicated that broadside fire was more important than that directly ahead and astern, it is preferable to place turrets on the middle line, so that the guns may be available on either broadside. It was this desire to get as many guns as possible to bear on either side which led to the adoption of superposed turrets in the *Kearsarge, Kentucky,* and other vessels of the United States navy: above each turret for the main armament a smaller turret with two 8-inch guns was placed, so that both could revolve together, thus practically constituting one turret with four guns. This makes for economy of weight and space, but exposes a large proportion of total battery power to disablement by a single shot or from breakdown of

the operating gear: it naturally also precludes the independent manipulation of the two pairs of guns, and has not been repeated in later vessels having a similar armament.

The best positions for turrets are undoubtedly those utilized for main armament in two-turret vessels, as the guns may be fired either right ahead or right astern, and have horizontal arcs of fire of 120 to 135 degrees on either broadside from the middle line. In that position, too, the propellant, stowed vertically under the guns, is away from machinery compartments, so this source of heat cannot cause deterioration of the ammunition. When more than two turrets are adopted, the problem becomes more complicated, as, in addition to the difficulty of getting good storage for ammunition, the adoption of large turrets towards the middle of the vessel involves cutting away considerable portions of the upper deck in regions where large bending moments are experienced at sea. Compensation for loss of strength is therefore required, which involves additional weight, whilst if the turrets are placed on the middle line the large arcs of training required restrict the space available for stowage of boats and installation of the smaller guns carried. The illustrations show how the problem has been solved in the British and United States navies, respectively. In the *Dreadnought* three turrets are placed on the middle line and one on each side, thus allowing eight guns to be fired on either broadside, and four, or possibly six, simultaneously ahead or astern. In the *South Carolina* all four turrets are on the middle line, the after one of the foremost pair being raised sufficiently to allow its guns to fire directly ahead over the foremost turret, and similar arrangements obtain aft; hence all the guns can be used on either broadside, and four directly ahead or astern if required. This arrangement enables the 14-pounder guns to be placed above the upper deck between turrets, and gives good boat stowage, at the cost of gun concentration at each end, a somewhat higher center of gravity of armament, and the possibility of interference between turrets when one pair of guns is firing directly over the other either ahead or astern.

All the vessels named in the preceding tables, with the exception of *Iowa,* have submerged torpedo tubes, but the question has been seriously raised as to whether the torpedo

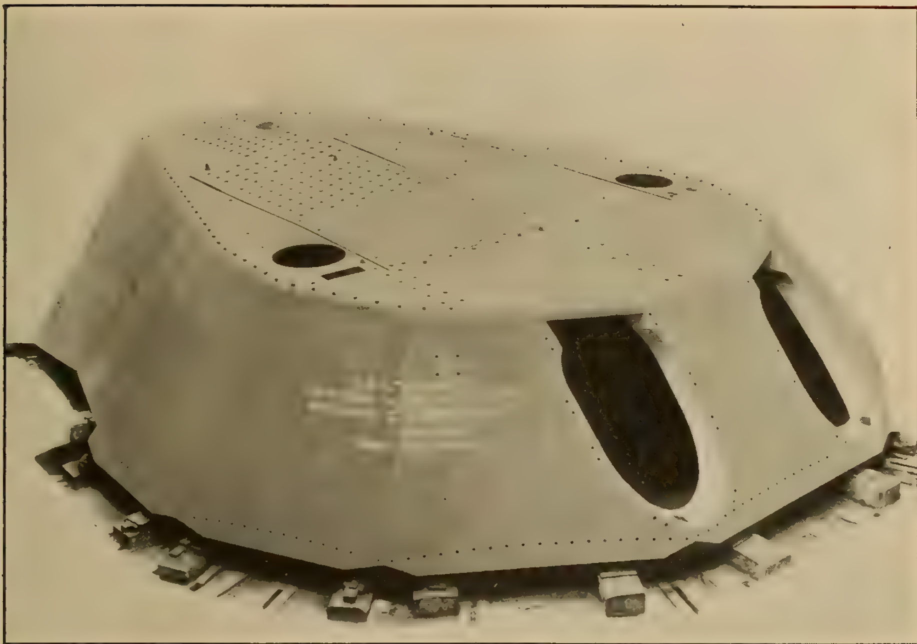


H. M. S. INVINCIBLE

equipment should not be omitted from battleships, seeing that the normal range at which actions are likely to be fought are outside the limits of use of even the latest and most powerful type of torpedo. Certain it is that in the late Russo-Japanese war no case occurred of a successful torpedo attack delivered from a large vessel; and the only torpedo attack on any large fighting vessel which resulted in sinking the ship thus assailed was that in which the *Kniaz Suvaroff* was sunk, and this vessel had previously received great damage from gun fire. The absence of torpedoes from *Iowa* is evidence of change of opinion on this subject in the United States navy. At the time of her design it was not thought desirable to fit under-water discharge in battleships, bearing in mind the limited range of the torpedoes then in use and the sacrifice of space, etc., involved in the installation. Later on, the speed, range, and accuracy of torpedoes having been greatly increased, under-water discharge was re-introduced into subsequent United States vessels, in the belief that torpedoes would be effective up to 3,000 yards, the maximum range at which it was then thought naval actions could be fought with decisive results. Now, however, it seems probable that future battle ranges will lie between 7,000 and 10,000 yards, and the question of the utility of installing torpedoes in battleships again obtrudes itself. The fact that up to the present they have been retained in all navies indicates a belief that in the unforeseen chances and changes of a naval action, opportunities may occur for usefully employing the weapon in question.

The ram used to be classed as an offensive weapon, but has been dwindling in importance for many years, and the spur bow is now disappearing from warships. After the ramming of the *Re d'Italia* by the *Ferdinand Max* at Lissa in 1866 the ram was in high favour, and all battleships had their bows specially strengthened for this form of attack: and not many years ago the *Polyphemus,* in England, and the *Katahdin,* in the United States, were specially built to utilize the ram as the chief weapon. Theoretical considerations, however, indicated the difficulty of using a ram against an enemy in possession of his manœuvring power without the attacking vessel standing an equal chance of being herself rammed; a conclusion borne out by experiments with small vessels specially prepared. Then, again, the introduction of the torpedo made the near approach to even a partially-disabled antagonist a hazardous proceeding, and as a matter of fact there has been no attempt to use the ram in any modern naval war. Under these circumstances, therefore, no surprise can be felt at the decision not to fit the specially-shaped ram bow to future vessels.

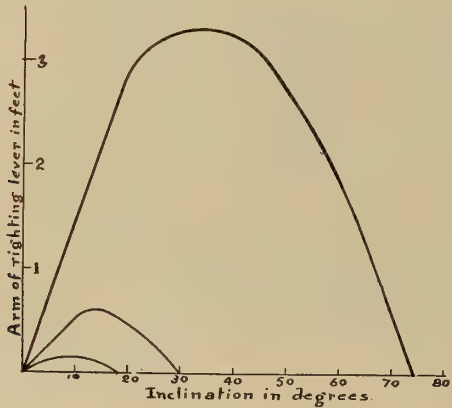
Turning next to the defensive arrangements of battleships, these, it has already been noted, should be such as to ensure the ship as far as possible, and in equal degrees, against all the various modes in which she may be disabled or destroyed. To this end it is necessary to shield against too extensive damage those parts of the vessel upon which buoyancy and stability depend, and to protect against attack the main armament and such vital parts as the motive power, magazines, and steering gear. Generally speaking, the means adopted for protecting the buoyancy and stability serve also to guard the other important elements. The buoyancy is supplied by the portion of the vessel below the water line, and is thus most liable to attack by locomotive torpedo or by mines; but can also be impaired by gun fire, either through projectiles which enter the ship above water and pass out at the other side below water; by a shot striking the bottom as the vessel rolls away from the attacking ship, or, whilst a ship remains upright, her bottom plating may be partially exposed at the hol-



GUN HOUSE FOR 12-IN. GUNS FOR H. M. S. BULWARK. C. CAMMELL & CO., LTD., SHEFFIELD

low of a wave as it passes the vessel, and a lucky shot may strike the exposed part at the critical moment. The stability depends upon keeping a large proportion of the water-line area, and of the part of vessel above water, uninjured; and is, of course, also affected (though not necessarily decreased) by damage of the ship below water. To protect against gun attack in the region of the water line, vertical and deck armour are employed, and thick armour also shields the heavy guns and conning stations. As a further means of limiting any damage occurring "between wind and water" the ship in that neighbourhood is divided into relatively small water-tight compartments, of which some may be kept empty, whilst others contain coal or stores. In some vessels, too, compartments towards the ends have been filled with cork for the same purpose of limiting the inflow of water, whilst in others (built abroad) cofferdams have been constructed in the neighbourhood of the sides, and filled with cellulose, which material, in contact with any water admitted in consequence of perforation by shot, is intended to expand into the hole and so prevent further ingress of water. In "protected" ships, indeed, compartmental sub-division in association with a protective deck (constituting what is known as a raft-body) is the only means adopted for securing limitation of damage from gun attack. There have not been wanting advocates of this method of protection for even the largest vessels, and it will be remembered that the *Italia* and *Lepanto*, 15,500-ton battleships, built by Italy about twenty-five years ago, depended for defense of buoyancy and stability entirely upon such means. Sir Nathaniel Barnaby, a former director of naval construction, has been a consistent advocate of this method of protection, and only a few years ago wrote: "The difficulties attending the question of the defense of buoyancy and stability against the gun are so serious that there is room for great changes in

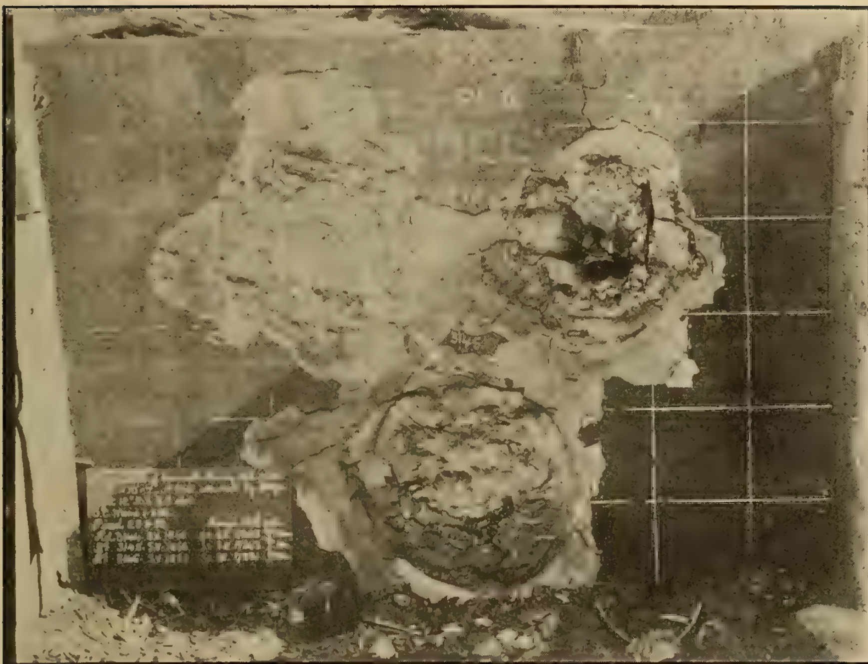
the future. The author's firm belief is that side armour will be abandoned, and that the raft-bodied system will enter upon a new phase." There is no evidence of such change at present: indeed, the symptoms point the other way, for cruisers with side armour have been built within the last few years, instead of the earlier large "protected" vessel of similar



CURVES OF STATICAL STABILITY OF THE INFLEXIBLE

type, and armour on battleships is universal.

An excellent illustration of the dependence of stability on that portion of the vessel which is above the water line is afforded by the diagram showing results of investigations of the committee appointed in 1877 to consider the design of the battleship *Inflexible*. That vessel had a strongly-armoured central citadel for about one-third her length, and a raft-body at each end, the numerous compartments above the under-water protective deck being filled with cork or stores. The large curve shows the statical stability of the vessel at various angles, assuming the vessel to be undamaged. Under these circumstances the metacentric height was 8¼ feet; the angle at which the vessel experienced her greatest righting moment was 31.2 degrees, when the length of arm of righting lever was 3.28 feet; and the vessel would not overturn until an angle of 74.3 degrees was reached. If, however, the unarmoured ends had been "riddled" by gun attack, so that water could find access to all unoccupied space above the under-water deck, the stability would have been reduced to the extent shown by the second curve, the metacentric height being then 2 feet; the angle of maximum stability 13½ degrees, with a length of arm of righting lever of .57 feet, whilst the range of stability would have been reduced to 30 degrees. Moreover, assuming all cork, and stores other than coal, blown out of the ends by the action of shell fire, the stability would have been still further lessened, as indicated by the small curve. In that condition the metacentric height would have been .24 feet; the angle of maximum stability 10 degrees, and corresponding length of arm of righting lever .12 feet; and the vessel would overturn if inclined beyond 17.4 degrees. Whilst, therefore, in the condition represented by *B*, the vessel would still retain a fair amount of stability, she would, if damaged as assumed for curve *C*, be in a very critical condition, and would, as the committee remarked, be likely to overturn if manœuvred at speed, whilst serious heeling would result unless the turret guns were run in and out with extreme caution; further, the small residuum of stability remaining would be quite insufficient to prevent a successful torpedo attack being other than fatal. The ship could be reduced to this serious condition, it will be noted, without perforating or otherwise damaging the heavy side armour, and emphasizes the importance of protecting by thick armour an adequate proportion of the side above water. The *Admiral* class had a narrow partial water-line belt proportionately longer than that adopted in *Inflexible*, and had strongly-plated under-water decks at ends: but the later turret ships *Nile* and *Trafalgar* had an arrangement of citadel and belt armour similar to *Inflexible's* with these parts very much longer in proportion to the total length of ship, so that in these

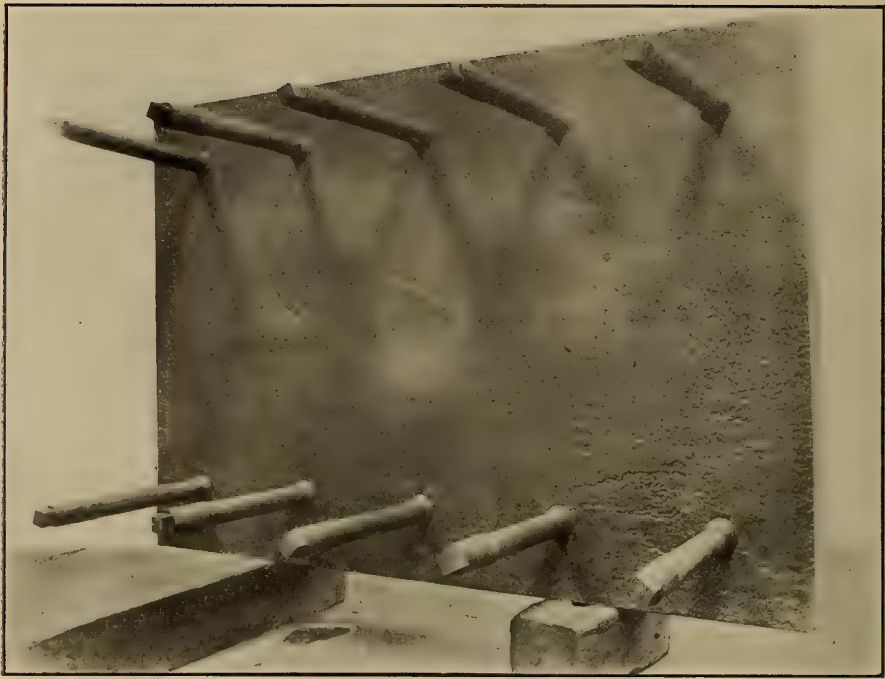


TEST AT SHOEBURYNESS, SEPTEMBER 29, 1898. CAMMELL-KRUPPED ARMOUR PLATE 11.66 INCHES THICK. CONDITION AFTER THIRD ROUND

vessels a very considerable area of side above water was protected by thick armour. In the early days of the quick-firing gun the French *Dupuy de Lome* had the whole of her sides above water covered with armour about 4 inches thick, but the general practice with battleships is to cover a smaller proportion of the total area with thick armour, sufficient to protect the "vitals" against likely damage, and to preserve intact enough stability to prevent the vessel overturning even after being under prolonged gun fire.

It will be evident that perforation by shot or shell at or below water may result in disablement of machinery or explosion of magazines, whilst a hole so situated is difficult to deal with by leak stoppers; for these reasons a good proportion of the length of ship should have heavy protection at the water line. On the other hand, experience gained in recent naval battles indicates that a hit on or near the water line is of rare occurrence, and that comparatively few shots strike much below the upper deck, and this fact should also be considered when determining the defense to be given to water line. It may be remarked here that the lower edge of armour belt is placed in all navies about 5 feet below water, the chances of a shot entering below this whilst the vessel is rolling, or during the passage past her of the hollow of a wave, being very small: it is therefore better to reinforce above-water protection rather than utilize weight in carrying the belt further below water. For a vessel loaded beyond normal draft the risk of a shot striking below the belt is further minimized; on the other hand, the armoured freeboard is lessened so that the stability with unarmoured parts damaged would probably be less than in normal conditions.

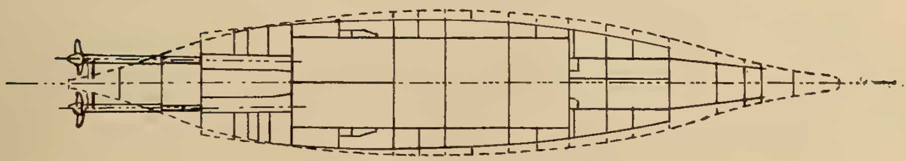
At the beginning of the period under review the type of armour used was that known as *Harveyed* armour, earlier vessels, as *Royal Sovereign*,



TEST AT SHOEBURYNESS, SEPTEMBER 29, 1898. CAMMELL-KRUPPED ARMOUR PLATE 11.66 INCHES THICK. BACK OF PLATE AFTER THE TRIAL

having *compound* armour. Krupped armour marked a further stage of improvement, and has been adopted for all recent vessels, as indicated in Table II. Against uncapped projectiles, 11 inches of Krupped steel is equivalent to 14 inches of Harveyed steel, 20 inches of compound armour and 25½ inches of wrought iron: and 9 inches of Harveyed steel is rather more than equal to 14 inches of compound armour.

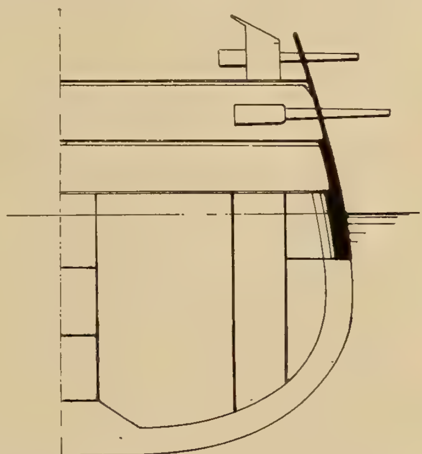
Turning to the arrangement of armour adopted, the *Royal Sovereign* type had a comparatively narrow, but long, belt of 18-inch armour, surmounted by a belt of 5-inch material, but in the later *Majestic* the side armour was made of uniform thickness throughout its depth and length, whilst the protective deck was carried to the lower edge of belt armour, as indicated by the half-midship section, instead of being continued horizontally across the ship at the height of upper edge of that armour, as usual in the earlier types. By the new plan the deck armour becomes available to resist the further passage of a projectile should it have succeeded in perforating the thick side armour, and this method of protection was subsequently adopted in other navies, although recent United States designs indicate a return to the earlier practice. The continued development of the quick-firing gun emphasized the importance of armour protection over large areas, and an examination of the plans of recent vessels shows that belts have been extended until now, as in such early ironclad ships as the *Minotaur* (completed 1861), they extend from stem to stern and for considerable heights above water. With water lines unarmoured at the ends damage could be effected in that region by quick-firing guns, and this, particularly forward, might result in the entry of such quantities of water as to materially affect the vessel's speed. Notwithstanding recent extensions of the area of protected side, a considerable



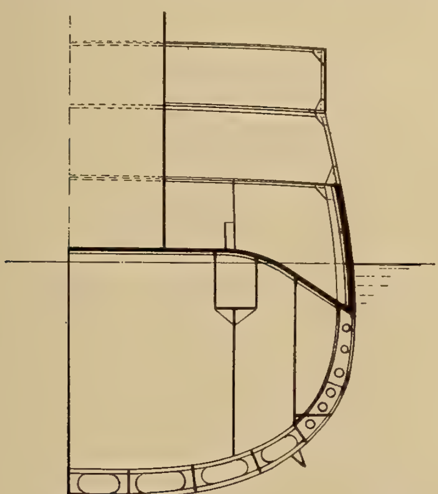
PLAN OF HOLD OF BATTLESHIP EXMOUTH

proportion of the ship above water is outside that area, and damage to this involves very considerable diminution of stability when the vessel is inclined, and renders her less able, by that amount, to resist further attack by heavy gun, mine or torpedo. This is one of the arguments of those who deprecate the omission of all secondary armament from battleships like *Dreadnought* and *South Carolina*, considering that weapons of the 9.2-inch or 6-inch types would prove, even at long ranges, very effective in destroying the unarmoured upper works of an enemy, and would accomplish this more rapidly than a smaller number of heavy slower-firing guns, even although a larger proportion of shots from the latter found their target.

Torpedo net defense is fitted to ward off torpedo attack, and water-tight subdivision is principally relied upon to minimize the effects of a successful under-water attack; the extent of this subdivision can be gathered from the plan of hold of the *Exmouth* and the section of the *Delaware,* which illustrates these particulars for two modern warships of different types. In the section of the *Delaware* it will be seen that the double bottom is carried right up to the protective deck, and there are also two longitudinal bulkheads intervening between that bottom and machinery compartments. The more minute the subdivision the more localized will be the injury; and the magazines should be kept so far in from the sides and bottom that intervening bulkheads and platforms may prevent the shock of any explosion on the outside of the ship being communicated to the ammunition with disastrous effects. The omission of water-tight doors from the main transverse bulkheads of British ships is an added element of safety, the inconvenience of having to go over the tops of bulkheads from one compartment to another being minimized by the provision of lifts. This omission

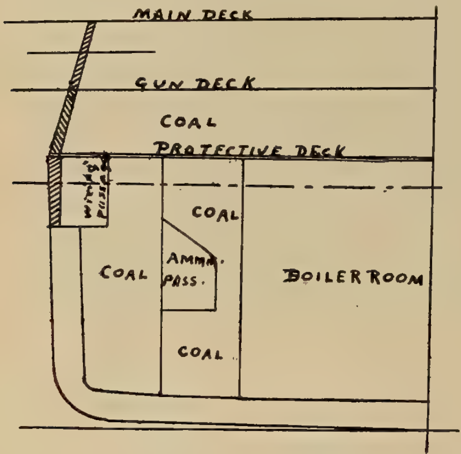


HALF MIDSHIP SECTION OF THE ROYAL SOVEREIGN



HALF MIDSHIP SECTION OF THE MAJESTIC

of communication at a low level between compartments has been tried before in the British navy, notably after the loss of the *Vanguard* in 1875 from collision with the *Iron Duke*. Such omission was, however, followed by complaints that the loss of communication affected prejudicially the proper supervision of the engine and boiler-room staff, and in many ships where doors had not been originally fitted they were introduced. As already mentioned, in



HALF SECTION OF U. S. S. DELAWARE

the latest vessels the provision of lifts and other appliances reduces this inconvenience to a minimum.

Suggestions were many years ago made to thickly plate the bottom of a vessel as a protection against under-water attack, but the pressure in the immediate vicinity of an under-water explosion is so enormous that no armour of practicable thickness on outer bottom could be expected to successfully withstand it: but in some modern vessels inner armour has been worked for this purpose, consisting of a thick plate longitudinal bulkhead fitted a few feet in from the side. Some of the earliest vessels having this protection were the Russian *Borodino* class and the similar but somewhat smaller *Cæsarewitch*. The last-named was attacked by torpedo boats at Port Arthur during the late war, and so severely damaged that it was necessary to beach her. The *Kniaz Suvaroff*, too, of similar design, was also sunk by such means, as already stated. It, therefore, appears that the provision for defense in these vessels was not such as to preserve them from serious damage from torpedo attack. On the other hand, the last-named vessel was subjected to repeated attack, and the comparative slowness of her destruction may well have been partly due to the thick bulkheads fitted. Such bulkheads placed within the vessel must certainly tend to limit the effects of under-water explosion to the region outside such bulkheads; but, in view of the weight involved, such inner armour has not been introduced into United States vessels, nor, it is understood, into those of France.

The late Russo-Japanese war furnished many illustrations of the effect on a ship of encounter with a submarine mine. From this cause the Russians lost the *Petropavlovsk*, *Boyarin* and the mine-laying vessel *Yencsei*, and the Japanese the *Hatsuse* and *Yashima*, not to mention smaller vessels. Seeing that this form of defense for harbours, etc., is still being greatly developed, it is evident that, even after all arrangements possible on a vessel have been made to mitigate the effects from mine explosion, a wound from such a source is almost bound to be serious.

A consideration of the size and power of recent battleships serves to show the enormous strides taken since Ericsson's *Monitor* of 1,200 tons displacement was completed in 1862, which vessel may be regarded as the germ from which the modern battleship has developed. Nor does finality in size seem even now to be reached, and battleships displacing 25,000 tons are lightly spoken of. It is not easy to determine the upper limit of size for warships, since, as for merchant vessels, there are no serious mechanical difficulties in the way of building much larger and more powerful vessels than any yet laid

down. The policy of building monster all-big-gun battleships has been called in question by Sir W. H. White in a recent number of a well-known periodical; he advocates for this matter "thorough and impartial consideration by experienced men, capable of dealing not only with the questions of shipbuilding, ordnance and engineering which are involved, but of advising on larger questions of policy of which they form part." Arguments in favour of the type mentioned are that individual ships provide a maximum concentration of force under the immediate control of a single brain, and if they also possess superior speed they can, when employed in fleets against an enemy possessing a larger number of vessels of less individual power, concentrate upon the head of the opposing column and effect its destruction before turning their attention to the rear vessels. The simplification of fire-control in one-calibre ships has already been mentioned, and a greater total smashing power is possible at the longer ranges likely in future battles. On the other hand, the increase of size and power involves greater first cost and augmented expenditure to make harbours, docks, etc., deep enough and wide enough to accommodate the larger vessels, whilst the greater draught limits their usefulness in shallow waters and canals. Moreover, concentration of enormous offensive and defensive power in single ships must tend to limit the number built, and a point may be finally reached when it becomes expedient to limit size in favour of numbers of ships. Also, from the "too-many-eggs-in-one-basket" point of view, the destruction of such a vessel by accidents similar to those which befel *Iéna* and *Mikasa,* or by grounding, as in the case of the *Montagu,* would represent loss of a considerable fraction of power; and the larger target presented by such vessels makes them more liable in warfare to hits above and below water, although the probability of any one blow being fatal diminishes with increase of size. The growth of size and cost is no new feature, and on some occasions it was hoped that finality had been reached. The designer of the new *Fury* (afterwards the *Inflexible*), for example, reported: "It may be that the limit of size and cost has been reached in the *Fury,* and that, with her bulk and cost, the maximum of advantages may be obtained. We are ourselves disposed to think that this is so and that there may be retrogression in this respect as more experience is gained with the powers of the torpedo, the ram, and other submarine instruments of attack." Subsequent history showed this to be true only temporarily. History indeed is, in general, a record of increase, although there have been times when the pleas for moderate size and economy have had weight. Thus, after the *Agincourt* (1866) of 10,700 tons displacement came the *Bellerophon* of 7,550 tons, and after the 1875 *Dreadnought* of 10,800 tons the *Alexandria* of 9,500 tons was built. In more recent times the *Canopus* class of 12,950 tons followed the heavier *Majestics,* whilst in the United States Navy the 16,000-ton *Connecticut* class was followed by the *Idaho,* of 13,000 tons displacement. From historical considerations, therefore, it seems probable that the power of the largest battleships will continue to increase, if but slowly; whilst concurrently with that development it is likely that somewhat smaller ships of less individual power will be produced, having the desirable quality of more moderate draught.

THE DESIGN AND BUILDING OF MODERN CARGO STEAMERS

By S. J. P. Thearle, M. I. N. A.

THE world's commerce upon the seas is for the most part carried on by cargo steamers; that is to say, in steamers designed and built for the sole purpose of carrying cargo, and not in any way intended for passenger, mail or other service.

The fast ocean liner is, without doubt, a more picturesque object, and one more calculated to excite general interest, than is the ordinary cargo steamer or, as she is now very commonly designated, the ocean tramp; besides which the passenger and mail steamer serves the important purposes for which the cargo steamer is not adapted. The former doubtless occupies the higher grade of the two among mercantile vessels, and deservedly so; but if the relative importance of the types were gauged by the amount which the whole body of each type contributes to the world's wealth, then the cargo tramp's pre-eminence would at once be recognized.

This type of vessel is distinctly British, and our neighbors across the channel show that they realize this by adding to their already copious vocabulary the term "cargo boat" to designate a type of steamer for which the French language had not provided a suitable name.

It is with the designing and building of this vessel that we are now concerned. Had we to start in each case with a clean sheet of paper and no accessories other than a lead pencil our task in designing an ocean tramp would be a more laborious one than, happily, it really is in a British shipyard.

The cargo steamer is now a highly specialized production, just as is a bicycle or a motor car, and so the builder of an ocean tramp has in his drawing office many pigeon holes so filled with data that he is able at very short notice to produce the plans of any such vessel for which he may be asked to tender. Although this is the case, yet in every instance there are embodied in the design certain principles which, whether they were thought out yesterday or last year, are yet essential to its efficiency.

The first point to be considered in designing such a vessel, if we go back to first principles, is, then, what she is required to do. This requirement may be roughly summarized as that of carrying a certain dead-weight cargo upon a certain draught of water; of carrying this cargo at a certain average speed for a certain number of miles, and with reasonable safety both to crew and cargo.

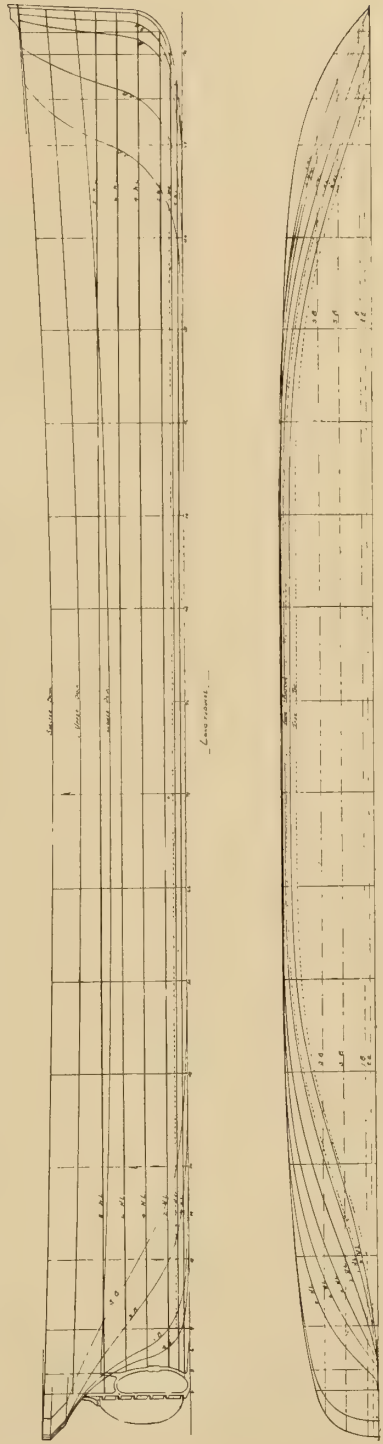
All this really means that a shipshape floating body has to be designed so that the water displaced by it at the specified draught shall be equal to the dead weight of cargo to be carried, plus the weight of the hull which can safely carry it, together with the weight of engine and boilers necessary for the desired speed, the weight of coals which would be required to keep the engines going at that speed over the entire distance to be covered and the weight of stores which would be consumed during the voyage.

In point of fact, the problem of designing a modern cargo steamer chiefly resolves itself into that of carrying the largest cargo on the smallest tonnage on which dues are paid, and in a ship having a minimum of broken stowage, due to beams, pillars, etc.

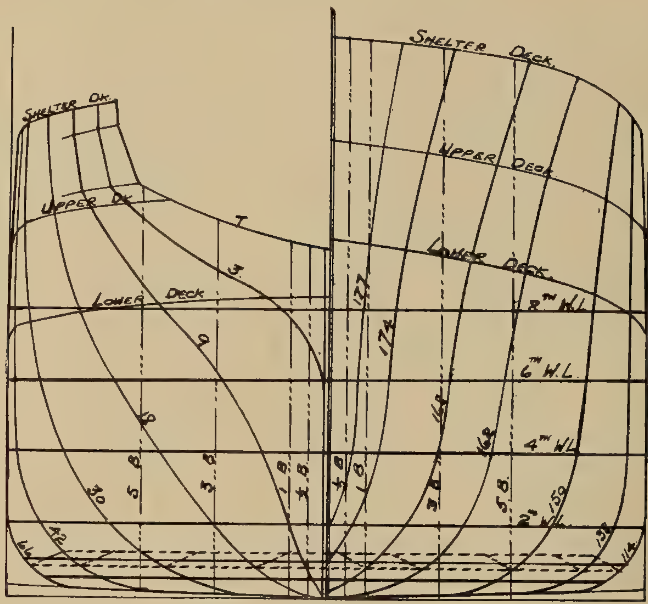
It will be observed that every addition to speed and to distance covered involves additional weight for machinery and fuel and additional space in the vessel for these things to occupy. So that the faster cargo steamer, capable of carrying a certain dead weight of cargo a given length of ocean voyage, is a larger vessel than the slower one need be, and the vessel with a large range of steaming power is a larger vessel than the one with a slower range, other things being the same. Hence, if the shipbuilder started in each case from first principles to design a cargo steamer intended to do certain things he would probably find himself approaching the final and accurate solution of the problem before him by a series of tentative efforts, each succeeding one of which would be nearer the truth than that just preceding it. This is, in fact, the course of procedure which is necessarily adopted in the case of any new and untried type of vessel. But the whole gamut of possibilities of cargo-carrying in ocean steamers has been often gone over by most British shipbuilders, so that for any dead weight of cargo, speed of vessel, draught of water, and range of steaming power, the builder has stored up data which enable him almost at a glance to fix the dimensions necessary for what it is proposed to do.

And here we come to a point upon which experts will sometimes decide differently from one another, and upon which practices vary from one time to another. We will suppose that the shipbuilder knows within a very close approximation what is the displacement which his vessel should have in order to do what is expected of her.

That displacement may be obtained in different ways. For instance, he may decide upon a ship which is shorter and therefore of greater breadth and depth than would another builder. Or, keeping to the same length, he may proportion the breadth to depth differently. Or,



PLAN OF LINES FOR CARGO STEAMERS

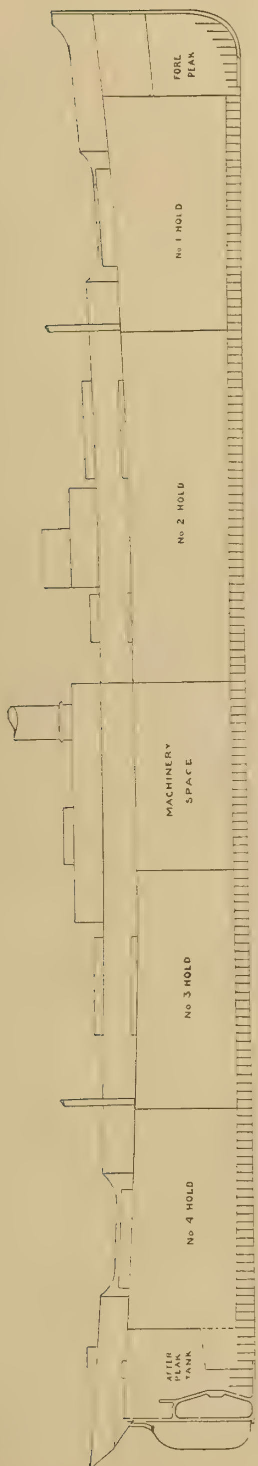


BODY PLAN OF CARGO STEAMER

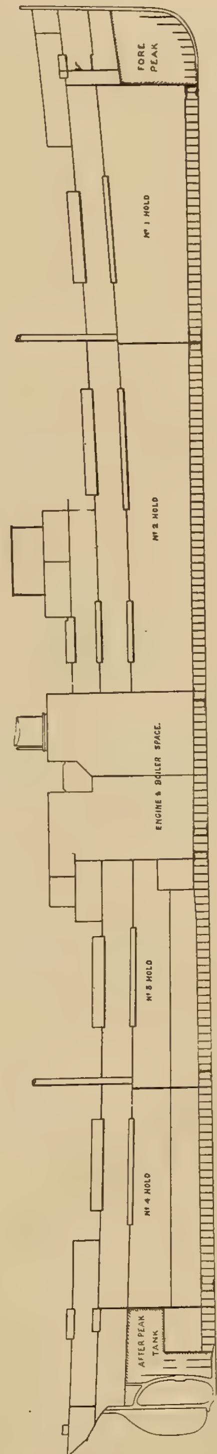
again, he may choose a fuller midship section and finer ends, or a smaller area of midship section and fuller ends, than would another designer of the vessel. These possible variations will, of course, influence the speed or engine power or coal consumption, for all the conditions entering into such a design are more or less interdependent. Of late years it has been the general practice to make the length about twelve to thirteen times the depth, and for the depth to be about 0.48 or thereabout of the breadth. These proportions apply to vessels of full scantlings. When a vessel is built with comparatively lighter upper works the relations of depth to breadth and to length are increased. So, too, as regards the fineness or fullness of the form of a vessel, the prevailing practice varies from time to time. The tendency of late years has been in the direction of fuller lines, and consequently diminished speed. About twenty-five years ago the displacement of a vessel averaged about 74 per cent. of that of the circumscribing rectangular figure, whereas at the present time it is often more than 80 per cent. These changes are really the expression of the economic experience of each period, vessels being built with a view to make the highest possible profit upon the money invested in them.

We thus see that when the shipbuilder of the year 1908 is asked to produce a design for a cargo steamer intended for some specific performance the conditions laid down determine within narrow limits the dimensions, proportions, and form of the vessel, so that several shipbuilding firms considering the question independently of each other will all arrive at dimensions, etc., which will not materially differ from one another.

There is one circumstance which contributes much to this uniformity of result. It will be evident that the weight of a vessel's hull will be an important part of her total displacement, and consequently the scantlings of plating, framing, beams, etc., adopted in any case will materially affect the result. That there is not in actual practice much variation in the weight of the hull of a vessel of any specified size is largely due to the



OUTLINE PROFILE OF A LARGE CARGO STEAMER WITH ONE DECK



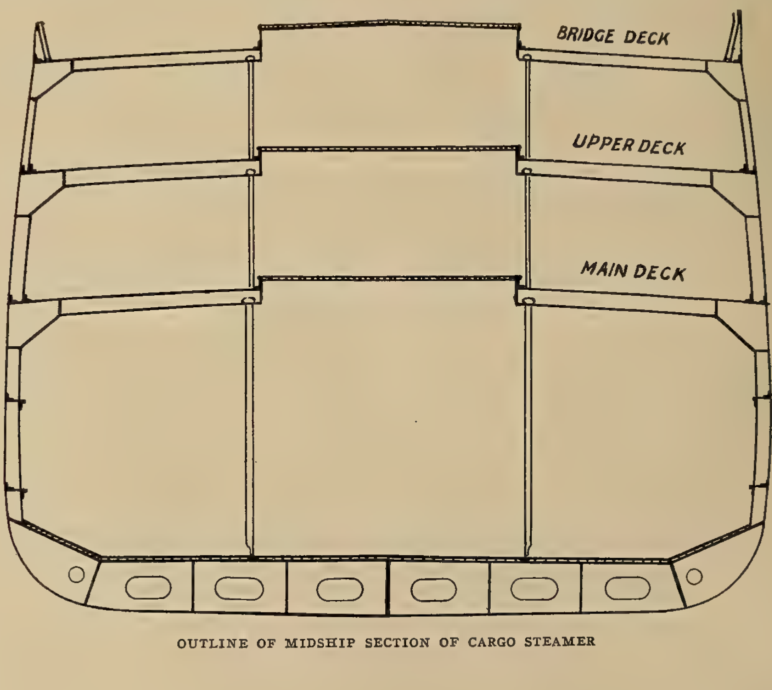
OUTLINE PROFILE OF A CARGO STEAMER WITH TWO DECKS

operation of the rules of Lloyd's Register of Shipping, which are necessarily adhered to in all classed vessels and more or less closely followed in all others.

Different designs of engines vary somewhat in their weight per horsepower developed, but such differences are not important. The height of vessel out of the water, that is to say, the amount which has to be added to the mean draught of water in order to arrive at the total depth of the vessel, is fixed by the Government freeboard rules and tables, which are almost identical with those recently legalized in Germany, and closely followed, although not insisted upon, by the law in other countries.

So far as we have gone, then, it will now be seen in what way the dimensions, proportions and form of a cargo steamer are arrived at. Questions of stability have, however, not yet been alluded to, although they lie latent in the practices which prevail. The actual stability of a vessel is finally determined, of course, by the character and storage of the cargo when loaded or by the position and amount of her water ballast when in a light condition. The proportions of breadth to depth which are found to prevail are based largely upon what conditions of stability show to be necessary. Widening a vessel tends to increase her initial stability, while deepening her in relation to her breadth tends to diminish her initial stability. Over and above these elementary principles it must always be borne in mind that, with a high freeboard, stability tends to increase up to a certain point as the angle of inclination increases, whereas with a low freeboard the angle is much sooner reached at which an increase of resistance to inclination diminishes. The data, pigeon-holed by a shipbuilder, to which he refers when preparing a cargo steamer design, have within them, although perhaps not definitely expressed, a recognition of those principles of stability, which must be observed in order that a cargo steamer may be efficient.

Having now got so far as the dimensions and form of the vessel, we have next to divide the hull into holds and spaces for machinery, etc., in such a way that the vessel will trim properly when the cargo is in,

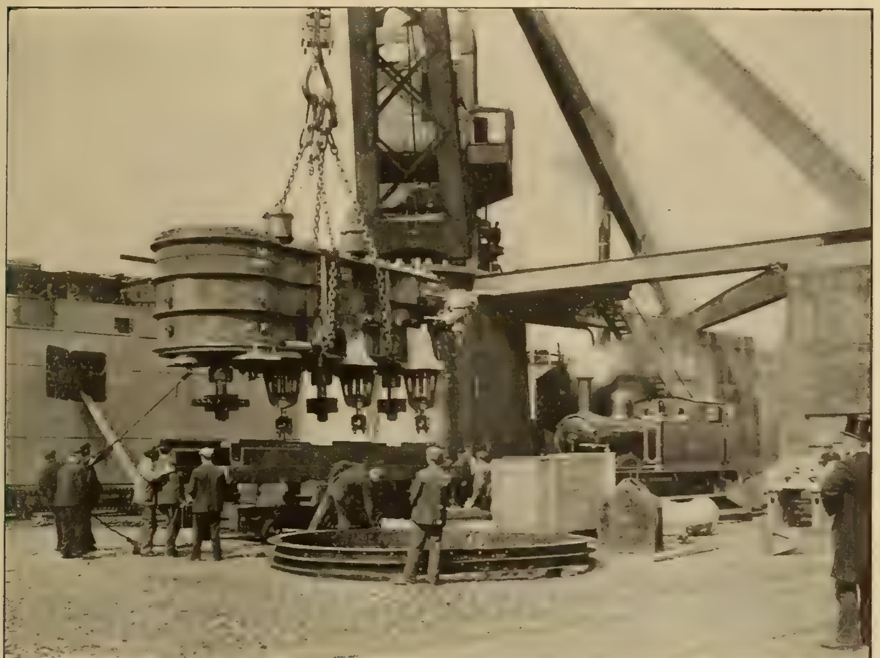


OUTLINE OF MIDSHIP SECTION OF CARGO STEAMER

and further, that her trim and immersion may also be suitable when in ballast.

Here again Lloyd's rules step in and fix the number of transverse watertight bulkheads in a classed steamer, according to her length. For instance, under 280 feet in length only four such bulkheads are required, viz.: one at each extremity of the engine and boiler space, besides a collision bulkhead and a bulkhead to after peak. At a length of 280 feet an additional bulkhead is required to subdivide the forehold and at 330 feet another bulkhead is required to subdivide the afterhold, but the omission of one of these intermediate bulkheads is sanctioned in some cases and under certain conditions.

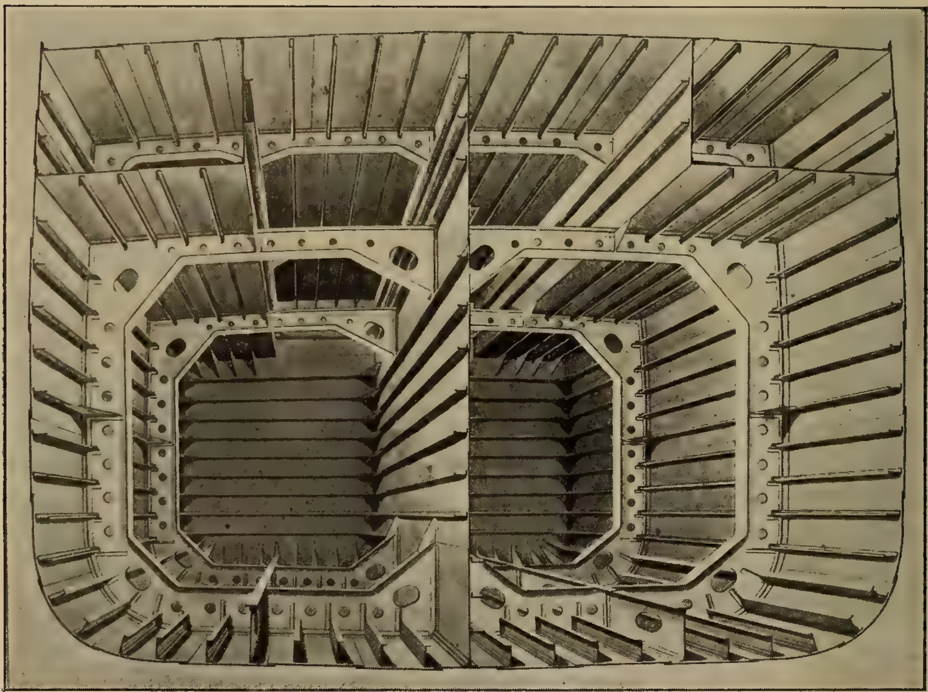
A cargo steamer does not usually require more than these six bulkheads. Indeed, the length of the ordinary tramp steamer, which may be said to range at the present day between about 300 and 380 feet, does not necessitate any further watertight subdivision. The position of the machinery space will clearly be the principal determining factor of the length of cargo holds; or rather, it would be more correct to say that a proper balance of the cargo before and abaft the machinery space, when the vessel is fully loaded with a homogeneous cargo, determines the position of the space devoted to carrying the engines, boilers and coal bunkers. When the cargo is out and bunkers are filled it is necessary that the screw propeller shall be properly immersed, for a great part of the steaming of a modern tramp steamer is done whilst in water ballast. For this purpose the after peak hold is usually a water-ballast tank; the double-bottom spaces are also used for the same purpose, and in some of the most carefully designed cargo steamers deep tanks are fitted, usually just before and abaft the machinery space, carrying sometimes one thousand tons of water in each tank, in order that when no cargo is on board the



HOISTING ENGINE-CYLINDERS ON BOARD

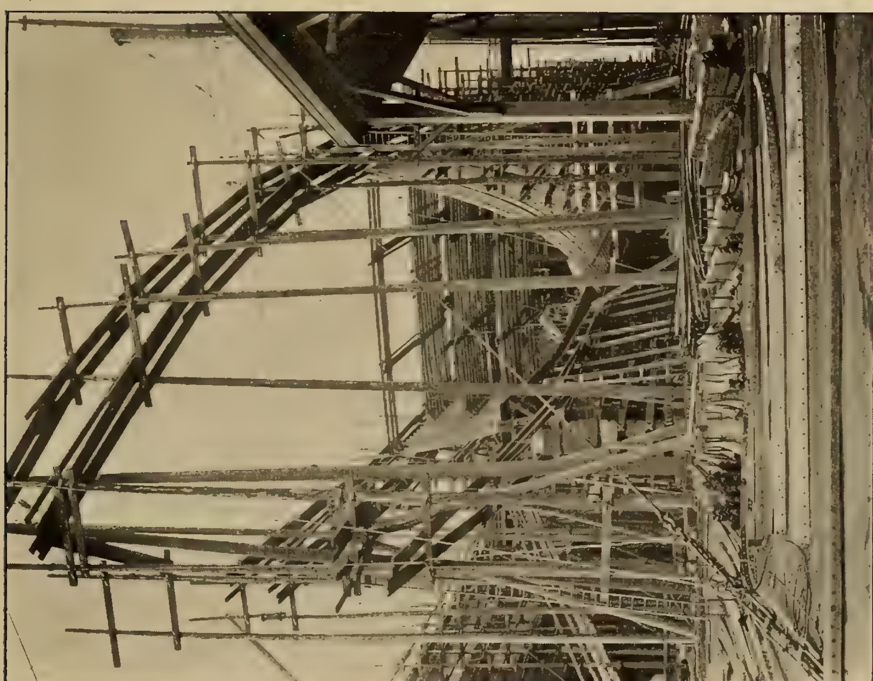
vessel may be sufficiently deep in the water to immerse the screw propeller and render her generally navigable and seaworthy. These deep tanks are, of course, also used for carrying cargo. When the deep tanks are not fitted it becomes necessary at times to carry shingle or other rubbish ballast to attain the same result in a less convenient manner.

Having divided up our cargo steamer into machinery space, peaks and holds, it remains to provide the necessary hatchway accommodation and means for getting cargo in and out of the vessel with facility. The dimensions of hatchways are much greater than formerly, and this has become possible only by means of the most careful and scientifically arranged structural details at these parts of the vessel. Many advances, too, have of late years been made in the provision afforded in the form of derrick posts, derrick cranes, etc., for loading and discharging, the power being obtained from steam winches on deck. Masts now serve little or no other purpose than as standards for the security and working of cargo derricks. Sails are disappearing, and in some types of cargo steamers have wholly disappeared. One or two stay-sails for steadying purposes in a beam sea are all that are carried in any case. The cargo steamer has, in fact, become specialized into a floating warehouse, driven by steam and filled and emptied by means of its own steam machinery and hoisting appliances. She is not, however, a very complicated structure, and when we have done so much as has already been described very little further remains so far as the design is concerned. We have after that to build what our plans indicate.

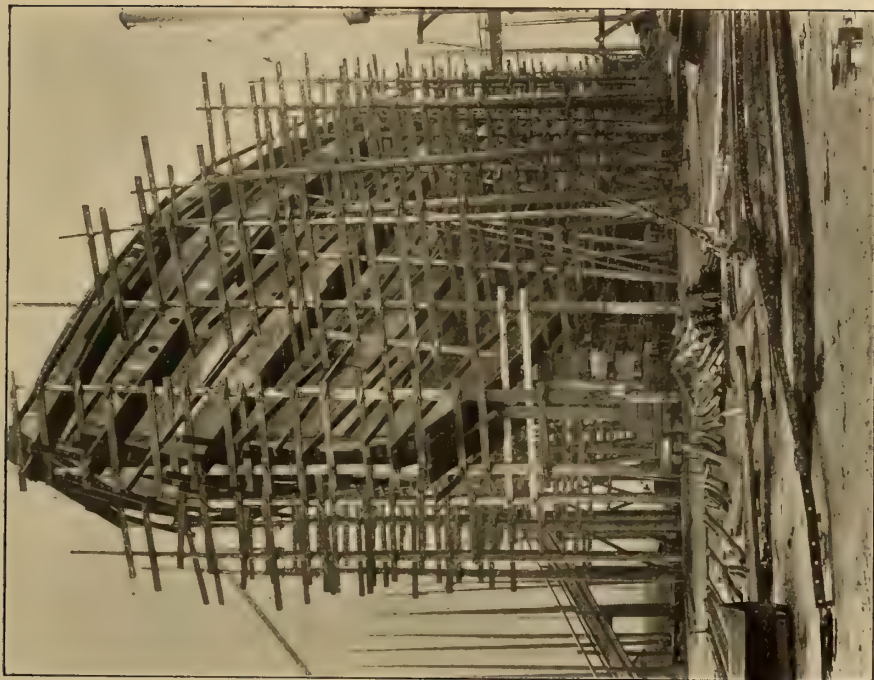


STEEL-SCREW OIL-TANK STEAMER PAUL PAIX, SHOWING ISHERWOOD SYSTEM OF FRAMING.

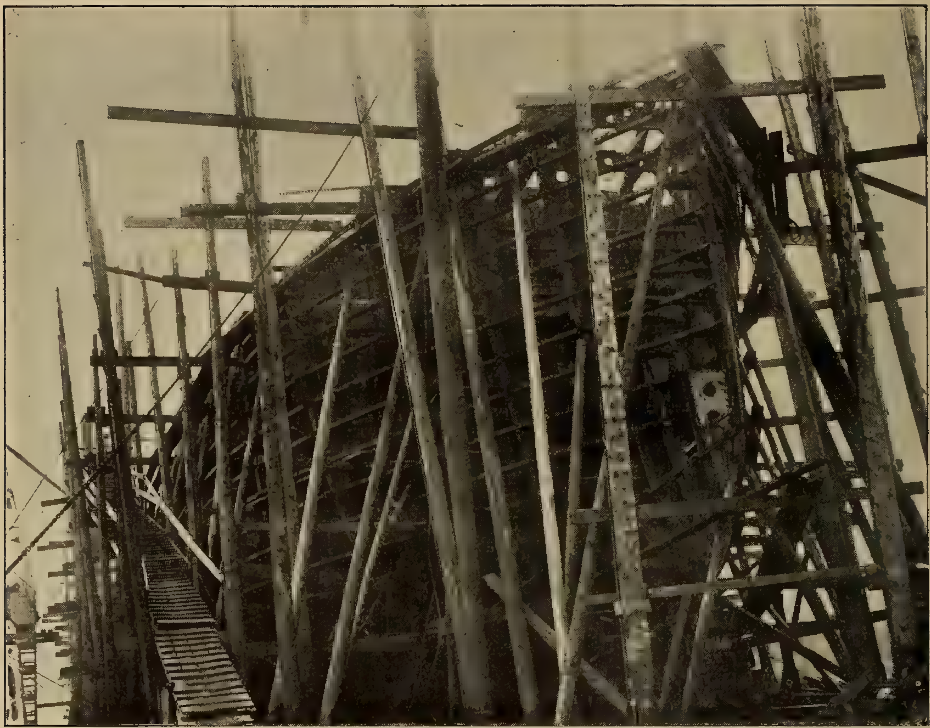
The illustrations on pages 29 and 30 show the state to which we have advanced. The first is the "sheer draught" of a cargo steamer, and shows the "lines" of the ves-



FRAMING ABOVE DOUBLE BOTTOM PARTIALLY ERECTED



HULL PLATED AND NEARLY READY FOR LAUNCHING



LONGITUDINALLY-FRAMED VESSEL READY FOR PLATING

sel as laid down on the floor of the mould loft so that the various components of the structure may be made of the form and dimensions necessary in order that the designer's intentions may be accurately realized. In the body plan the shape of the cross sections indicates to the trained eye precisely what the form of the vessel will be when built. To explain fully the actual relation between the lines in all the plans and show how the vessel is laid off would be rather the function of a treatise than a brief magazine article. It must suffice to say that everything necessary to insure that the form of the vessel shall be as intended is contained in these plans.

Page 31 gives longitudinal elevations of the vessel known as the "profile." As will be seen, it shows the position of the bulkheads, cargo holds, machinery space, hatchways, mast derricks, etc., etc., as designed to carry out the object of the owner for whom the vessel is built, and that, too, in an efficient and economical manner. On page 32 is shown a "midship section" giving the structural arrangements and scantlings. These scantlings are, in short, Lloyd's rules as applied to these particular ships.

It must not, however, be supposed that the design of the cargo steamer always follows some stereotyped arrangement. On the contrary, there is far more variety of type among such vessels than is to be found in steamers designed primarily for passenger service. We find, for instance, such diverse forms as "turret steamers," "trunk steamers," "cantilever-framed" vessels, "side-ballast tank steamers," and quite recently there has been introduced the longitudinal system of construction as patented by Mr. Isherwood. Moreover, there are the special designs of vessels for carrying petroleum in bulk, usually spoken of as "tankers," which constitute a class wholly apart

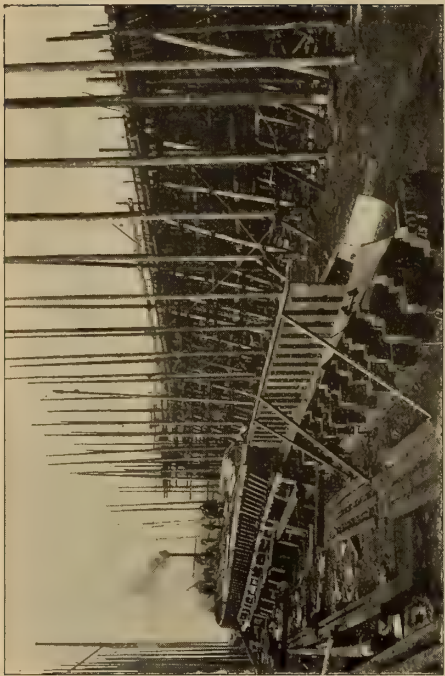
from the ordinary cargo boat, and for which special structural arrangements are necessary. Our illustrations of vessels in different states of construction show steamers of these different types.

Our ship is now designed, and has to be built; it is to that part of the subject we now give our attention.

Let us suppose a proper place selected for building the cargo steamer in the shipyard, and blocks laid at the height and declivity suitable for building her upon, so that she may be readily launched when built. These are important details, although thus so summarily dismissed.

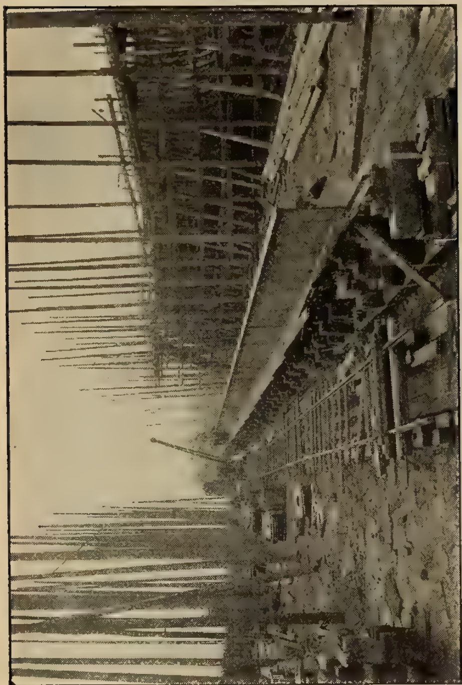
Nearly all modern cargo, and indeed other steamers, are built with flat plate keels, the object being to get as little draught of water as possible. Any tendency to rolling which might result from the omission of a bar keel is generally checked by fitting bilge keels, which do not add to the draught of water. The flat keel plate is therefore the part of the vessel first laid on the blocks, and upon it, in the case of a double-bottom steamer (the almost invariable type) the center girder is erected. While this is being done the transverse framing of double bottom is preparing. Each member of that framing consists of a deep floor plate, with a frame angle on the lower edge and a reverse frame angle on the upper edge; the former for attachment to the outer bottom, and the latter for attachment to the inner bottom plating. These are erected on each side of the center girder and connected to it by angles. When placed and supported temporarily in their proper positions and faired they are riveted to the center girder, after which the "margin plate" of double bottom is secured to the outer ends of the floors. At this state of the work two different courses of procedure are adopted. On the north-east coast of England the outer bottom plating is next fitted and riveted, while on the Clyde the inner bottom plating is first put on.

MR. GLAISHER'S SIDE TANK SYSTEM SHOWN IN FRAME



DOUBLE BOTTOM PARTIALLY FRAMED

INTERIOR VIEW OF A TURRET STEAMER



FLAT KEEL PLATE AND CENTER GIRDER ON THE BLOCKS

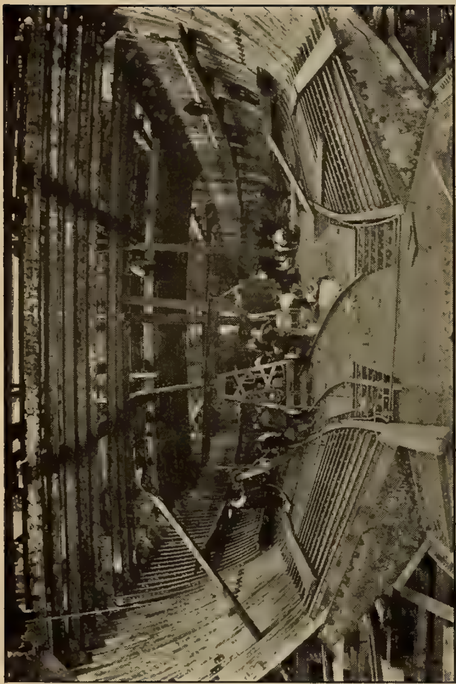
CANTILEVER-FRAMED VESSEL, DIXON AND HARROWAY'S PATENT

Then comes the erection of the framing above the double bottom. One of the chief features which distinguishes the average cargo steamer of to-day from her predecessor of ten or fifteen years ago is that of the side framing. In her earliest form the cargo steamer's frames were formed with a comparatively small frame and reverse angle riveted back to back. This vessel often had two decks and large stringers in hold. by bulb angle frames equal in strength to the riveted deep frame, but not so liable to waste through corrosion, and not so objectionable from the cargo-stowing point of view as the built-up frame and reverse frame. Whichever be the type of frame adopted, and whether the vessel be of the "turret," "trunk" or other transverse system of construction, the method of erecting the side framing above double bottom is the

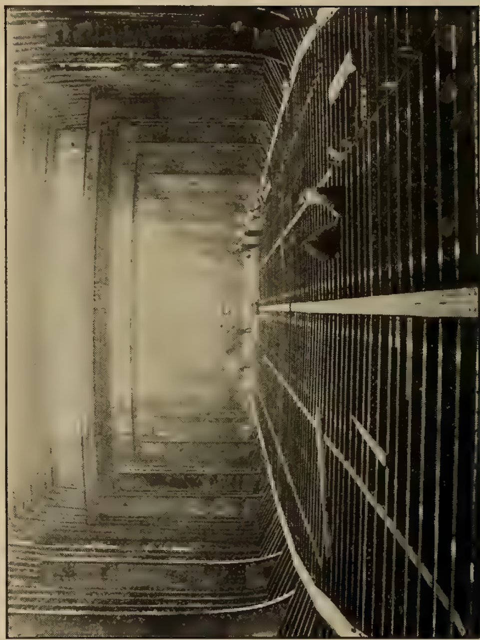
INTERIOR OF A TRUNK-DECK STEAMER

Then followed an effort to dispense with tiers of beams and wide hold stringers, and this result was at first achieved by fitting web frames at distances of 8 or 10 feet apart. This is a strong arrangement, but it interferes with cargo stowage, and so the next step was to substitute frames composed of much larger frame and reverse angles associated with comparatively narrow side stringers. This type of framing termed "deep framing" still persists, but its place is rapidly being taken

same. These frames are kept in place by ribbands and shores until the beams are lifted and attached. The whole structure is then carefully faired and adjusted preparatory to receiving the shell plating. And here seems to be the proper place to refer to the joggling systems which of late years have largely entered into steel ship construction, having for their object the dispensing with packing slips between the frames and the outer strakes of plating. There are two methods of doing this, advan-



A BUSY INTERIOR



INTERIOR VIEW OF WEB-FRAMED VESSEL

FRAMED AND INNER BOTTOM PLATING COMMENCED

INTERIOR OF LONGITUDINALLY- FRAMED OIL-CARRYING STEAMER

S. S. CITY OF KARACHIE, ELLERMAN LINES, LTD.

tage being taken in each case of the highly ductile qualities of mould steel. By the earlier method the laps of the outer strakes of shell plating are joggled over the inner strakes, but by a method of more recent origin the frame angle bars have joggled indents made in them for the breadth of each inside strake of plating.

The necessity for using packing is dispensed with by each method, and consequently an important economy of weight is thereby effected. The application of the two systems of joggling is not, however, limited to the shell plating. By joggling the laps of alternate strakes of deck plating or by joggling the beams, the use of packing is dispensed with at

S. S. WAYFARER

the decks, and by similar means packing is saved at the inner bottom plating.

These are but two of the details of comparatively modern introduction which have been resorted to in order to reduce weight and increase efficiency. The increase in the length of individual plates is another. It is to the ever-growing skill of the steel manufacturers we are indebted for this improvement whereby the number of butt straps in the plating has been greatly diminished. Of such length, indeed, may steel plates of ordinary ship thicknesses now be rolled that the limitation to their use is fixed rather by the shipbuilders' appliances for fitting them into place than by any question of manufacture or price. Improvements are continually being made in the lifting appliances provided in shipbuilding yards, but it is doubtful if these will succeed in keeping pace with the possibilities of steel manufacture.

The shell plating of cargo steamers is almost wholly lap butted, but this is not a detail of recent adoption, having been practised for many years.

Deck beams are usually more closely spaced than formerly, especially at the weather decks. The tendency to buckling of deck plating when steamers are in ballast trim has been the main factor in bringing about the one-frame space arrangement of beams now so usual, and the same phenomenon has doubtless contributed very much towards the recent concentration of attention upon longitudinal arrangements of beams. Up to the present, however, the most usual mode of preventing buckling of decks has been by fitting intercostal arrangements of longitudinal girders at or about in a line with hatchway coamings and deck casings. The present requirements of Lloyd's Register, whereby scantlings of beams and the number of rows of pillars beneath them are adjusted in due relation to each other, have been largely responsible for a more scientific treatment of this part of the structure of a cargo steamer than was at one time to be observed.

With these improvements, others of an equally important character have been associated. The advantage of having holds as little obstructed by pillars as possible has been met by the adoption of widely spaced pillars of great strength supporting strong girders fitted below the beams and attached intercostally to the deck plating. In no particular is the modern cargo steamer more superior to her predecessor than in this of beam and girder structure and pillar support.

Bulkheads, even of cargo steamers, are better stiffened than formerly, but of late there has been a strongly indicated tendency to minimize the number of transverse bulkheads in cargo steamers so as to provide longer lengths of cargo hold for stowing certain descriptions of cargo, especially logs of timber.

The one outstanding and characteristic feature of the modern cargo steamer is, however, the reduction in the number of her decks; until at the present time the one-decked steamer is that most usually built.

Steamers up to about 30 feet in depth have been built in this way, and experience with them shows that they are not wanting in strength.

The frames of such vessels have, of course, been made very deep and strong, and the necessary transverse strength has been largely secured in this way.

Another interesting feature in the modern cargo steamer is the tendency to reduce the size, and even the number, of side stringers in deep-frame vessels. The length of an ordinary cargo hold is such that the depth of a side stringer is of necessity too small in relation to its length to prove an efficient girder, and hence it has come to be realized that the chief value of the side stringer is in checking any tendency of the framing to trip when under stress, and, by means of the intercostal attachment,

S. S. WHAKARNA

to stiffen the shell plating. Some cargo vessels have been built without any side stringers, and if they prove successful it will show that, with proper compensation, these portions of the structure may be dispensed with. Much interest will therefore be centered in the future career of these steamers.

While we have been thus discussing the details in the construction of the hull of our modern cargo steamer, the various parts referred to have been built in about the order to which reference has been made to them.

Our steamer must, however, be riveted, and this brings us to the important question of pneumatic versus hand riveting for water-tight work, and, indeed, for all important parts of the structure. In America the

S. S. GANDA

pneumatic hammer is largely used for the riveting of shell plating and elsewhere, and so it is in some parts of the Continent. But experience with that form of riveting has not always been satisfactory, and much as our shipbuilders would welcome any means whereby manual labour may be saved, yet the pneumatic-hammer system of riveting has not so far found favour in Great Britain or given satisfaction. There can be no doubt that up to the present no improvement on hand riveting has been invented for those parts of the vessel where hydraulic or "squeeze" riveting is impracticable, and consequently hand riveting prevails.

It is impossible in a magazine article to describe at all adequately such special types as oil-tank steamers or the particular features which characterize "turret," "trunk" and other special types. Our illustrations must serve to indicate wherein these vessels differ from the ordinary type. The fact that such various types have been designed and that they are all of them numerously adopted is sufficient evidence of the great vitality and enterprise which characterize cargo shipbuilding; and that all of them originated in the United Kingdom is evidence the people of these islands are showing no falling off in regard to those qualities which have made them the principal shipbuilders of the world.

THE FUTURE OF THE BRITISH FLEET IN ITS RELATION TO THE TWO-POWER STANDARD

By Archibald S. Hurd

FROM current public discussions with reference to the maintenance of the strength of the British fleet, it might be imagined that the British people had inherited what is known as the two-power standard from the time of King Alfred, the founder of British naval power. This formula is usually referred to with the reverence which is paid to an ancient tradition which has been handed down from generation to generation without variation and has been tested during hundreds of years in periods of stress and storm and has proved its title to respect so conclusively that it would be the rankest heresy to deny it.

The truth is, however, that the two-power standard—an indefinite term to which various meanings are attached—is a modern invention, devised to meet modern needs. It is of much later date than even the Monroe Doctrine. As to the exact meaning of the term there is no certainty. Literally it means that the British fleet should be just as strong as the two next greatest fleets in the world, but this is not the interpretation which it always bears. It is not a rule-of-thumb measure, but an elastic formula, sometimes meaning one thing and sometimes another. It is an entire misunderstanding to suppose, as might be imagined from the tone adopted by some speakers and writers, that the British Empire has been created by the influence of what may be styled a two-power standard fleet. As Macaulay, in beginning his History of England, remarks, "Nothing in the early existence of England indicated the greatness she was destined to attain," and this is especially true of British maritime power. Britain was not even regarded as of much importance as a sea power when Queen Elizabeth ascended the throne, and the British star did not rise until after the defeat of the Spanish Armada. "What Wolsey and Henry," writes Mr. J. R. Green, the historian, "had struggled for, Elizabeth had done. At her ascension England was scarcely reckoned among the European powers. The wisest statesmen looked on her as doomed to fall into the hands of France, or to escape that fate by remaining a dependency of Spain. But the national independence had grown with the national life. She now stood on a footing of equality with the greatest powers of the world. She had sprung at a bound into a great sea power." Rear-Admiral Sir Eardley-Wilmot has pointed out very appositely that to realize this, it must be remembered that up to that time Spain and Portugal were the foremost maritime countries. The former had discovered America, and was deriving wealth from her Western possessions, while Portugal, impelled to exploration by sea owing to her geographical position, was establishing colonies in the East. Bartholomew Diaz had rounded the Cape of Good Hope in 1486, and in 1498 Vasco da Gama anchored in Indian waters. Such was the progress made in those parts by the Portuguese that in 1505 Almeida was sent to India as Viceroy. Hence the surprise of Europe in 1588 that the mighty armament of Philip had been dispersed by a fleet which had hitherto gained renown

chiefly by piratical expeditions. This victory took the world by surprise. The fact is that England, in previous generations, formed a hardy race of seamen whose success in many fights, and in raids across the Channel, made them well fitted to cope in their own waters with such an enemy. The birthplace of the English navy was in that fishing industry carried on by the Cinque Ports flotilla, which had guarded the Channel during many reigns. A spirit of adventure and desire to obtain some of the wealth in distant parts, of which they had heard wonderful accounts, had led the younger generation to take service with Frobisher, Hawkins, and Drake; a service which turned out splendid seamen and enabled us later to compete with equal success against the Dutch. That nation now attained the chief place as a sea power, having defeated the fleets of Spain, and Holland eventually superseded Portugal in the Eastern possessions of that country. The decline of Portugal took place during her incorporation with Spain. England and Holland each formed a company, trading to the East at the beginning of the seventeenth century. Thus the two countries came into rivalry, and various incidents, such as the massacre of the English at Amboyna in the Moluccas, gradually led to hostilities.

England and Holland faced each other as keen commercial and colonial rivals, and between them was the North Sea. After the lapse of centuries almost similar conditions have again arisen, but in place of Holland we have the German Empire. Whereas in the seventeenth century England was an aspirant to power, now she is the greatest commercial and colonial empire the world has ever seen, and Germany, with her closely-packed population increasing at the rate of nearly 1,000,000 each year and requiring an outlet, and her increasing trade seeking for fresh markets, has adopted a policy of *welt politik,* which can succeed only at the expense of British power. In the long-continued struggle against the Dutch, which existed in the time of Cromwell and continued during the reign of Charles II., Britain fought with inferior naval forces, and victory sometimes went to one side and sometimes to another, but the terms of peace concluded in 1672 sufficiently indicate that the British fleet had, upon the whole, achieved considerable success. In the meantime, under Richelieu and Colbert, whose name is still honoured, the French Navy had made great progress, and during the final years of the seventeenth century, England, in alliance this time with Holland, waged war against France, and again succeeded in achieving some successes, this time at the expense of the French marine. During the eighteenth century France and Spain, hand in hand, endeavoured to check the growing sea power of Britain, and for a time it looked as though British power might be overthrown, not owing to the particular prowess of the allies, but through the want of co-operation between the senior officers and lack of discipline generally. Admirals were jealous of each other, and more intent upon humiliating colleagues than searching out the enemy and defeating him, and captains, taking their example from the higher ranks, were insubordinate, and some of them paid for their misdeeds with their heads. About this time Pitt, speaking in Parliament, declared "solemnly that his belief was that there was a determined resolution, both in the naval and military commanders, against any vigorous exertion of the national power." Fortunately the crisis produced the man. It was Lord St. Vincent who created the weapon which Nelson used with such master-genius at Trafalgar. First in active command, and then as First Sea Lord at the Admiralty, he devoted himself to the task of breaking down the disaffection which promised to lead to the complete

H. M. S. INDOMITABLE, FAIRFIELD SHIPBUILDING & ENGINEERING COMPANY, GLASGOW

overthrow of British naval power. As a disciplinarian he was stern to the verge of cruelty, and then Nelson came on the scene as the supreme naval commander, contrasting in every characteristic with his stern senior officer, to win for Britain an unchallenged supremacy on the seas, which for over one hundred years has not been contested. But this ascendency was not gained by a two-power standard fleet. At the battle of Trafalgar, Nelson could bring into line only twenty-seven ships in contrast with thirty-three of the combined fleet opposed to him.

It is one of the most remarkable incidents in history that the British people attached so little value to the peace which was finally sealed in 1815, that they consented to a continual reduction of the naval force by which alone that peace could be made permanent if there had happened to be an aspiring naval power at that time willing to risk much for a great prize. Mr. C. McL. MacHardy, in one of the excellent historical pamphlets of the Navy League which have done so much to educate public opinion, has thus summarized the subsequent course of British naval policy: "Then it appeared that England no longer attached any importance to retaining her supremacy on the sea, her naval forces were greatly reduced and she sent forth her ships of war jury-rigged, with reduced armaments and greatly diminished crews, line-of-battleships, some even bearing Admirals' flags, left behind them their lower-deck guns (the principal battery). The folly of this was apparent in 1840, when the Syrian question brought us to the verge of war. Notwithstanding that the number of seamen then required to reinforce the Mediterranean fleet did not exceed 4,000, and notwithstanding the great urgency of the case, six months elapsed before the first ship commissioned for the purpose could leave England for want of men; and the men so urgently needed to complete the crews of the ships already on the coast of Syria (many of which were very short of complement), were not only of extremely inferior quality, but could be raised only so slowly that scarcely any reached the fleet until the crisis was past."

This brings the story of the British fleet down to 1854, when the Crimean war occurred and Great Britain was spending only seven millions sterling on her navy. The campaign drew from the Emperor of the French expressions of surprise and disappointment at the feeble character of the assistance which the Royal Navy was then able to lend. While Great Britain had been pursuing a policy of cheeseparing upon the navy, Louis Napoleon had been devoting himself to an expansion of his naval power, until, in 1858, France had obtained a preponderance in ships of the line afloat, as well as in frigates building, and then with the conception of the first ironclad, *La Gloire,* the French designers rendered practically obsolete the large number of unplated ships which were being built in British dockyards. It was a case of the *Dreadnought* policy, but in 1859 it was France who took the lead.

From this short résumé of the rise and fall of British sea power, it will be seen that in these early years the British people set comparatively small value on the fleet, and the success of the British army in the Peninsular and in the Crimea served still further to divert attention away from the essential defense of an island kingdom. Pitt and Palmerston set great value on coastal defense, and money which should have been devoted to the fleet, which alone could secure the safety of the British Isles, was squandered by millions in ineffective measures to defeat our foes on our own shores. Lord St. Vincent was not only a great disciplinarian and administrator, but he also belonged to the "blue water school," and during his lifetime he

devoted himself to the lucid exposition of the "blue water gospel" in spite of the heresies which were then so prevalent, and which continued to hold sway in face of all the examples of history, and the denunciations of far-seeing officers, until captain, now rear-admiral, Mahan, took the world by storm with his powerful exposition of the influence of sea power upon history. This American naval officer, writing immediately after the British naval defense act of 1889, pointed out the "influence of sea power on history," and changed the course of the policy of the great nations.

STERN VIEW OF THE INDOMITABLE

Down to little more than a quarter of a century ago there was a keen competition among both political parties in the United Kingdom to reduce the expenditure upon

the fleet to the lowest possible limit, though that limit was incompatible with national security. In this rivalry the Conservative party vied with the Liberal party, with the result that in the early eighties the strength of the British fleet had been so greatly reduced and our position had become so insecure that public opinion, although then singularly badly informed on naval matters, was aroused and the professional politicians who had been too absorbed in party warfare to take account of the movement of events, particularly in France, were at last forced to turn their attention to the fleet. First, however, it must be recalled that when the Russo-Turkish war broke out in 1877, a panic scare arose and the House of Commons had suddenly thrown at it a peremptory demand for a special vote for the navy of six millions for a typical "scare programme." With this money a number of inferior ships were obtained at high prices, the fleet gained in strength hardly appreciably and public anxiety subsided. Even this incident left the professional politician blind to the course of events, and then in 1884, 1888 and 1893 followed the series of naval agitations, undignified in their expression, costly in their operation and baneful in their influence upon our relations with foreign Powers. Fortunately at this time France was the only power in Europe which devoted a considerable proportion of its revenue to naval defense, and in the early eighties public opinion rested satisfied with the standard of British expenditure which aimed to maintain the fleet at a slight margin of superiority to that of France alone, so that the professional politician was not greatly disturbed by the pressure which was put upon him to keep ahead of France in naval preparations. From year to year, however, the outlay upon the navy fluctuated violently. In spite of the naval agitation of 1885, in the opinion of the late Admiral Sir W. H. Colomb, the British strength in 1888 was less than that of France alone.

Then came the naval movement of 1888 and the setting up of what has since been known as the two-power standard.

When this movement of public opinion first became clamant, Lord George Hamilton, who was then First Lord of the Admiralty, refused to admit that there was any necessity for increased appropriations for the fleet. In spite of this assurance, the agitation proceeded throughout the length and breadth of the country, and at last a meeting in the city of London forced the hand of the Government, and Lord George Hamilton proposed a five years' programme of shipbuilding, which was incorporated in the naval defense act. In introducing this policy to the House of Commons, Lord George Hamilton made the following statement:

"Our supremacy on the sea must, after all, be measured by the number of battleships we can put into line. It is further our duty, as we find other nations pushing forward this particular class of ship, to do the same. I have endeavoured during the past year to study the speeches of those who, in previous years, have held my position and that of Prime Minister, so as to ascertain the paramount idea underlying their utterances when they spoke of the standard of strength upon which our naval establishment should be maintained.

"I think I am accurate in saying that *our establishment should be on such a scale that it should at least be equal to the strength of any two other countries.*

"I notice that the right honourable gentleman the member for Edinburgh (Mr. Childers) has given expression to that view, and has stated that he felt certain that when he left the Admiralty the British fleet was equal to the combined forces of any two other coun-

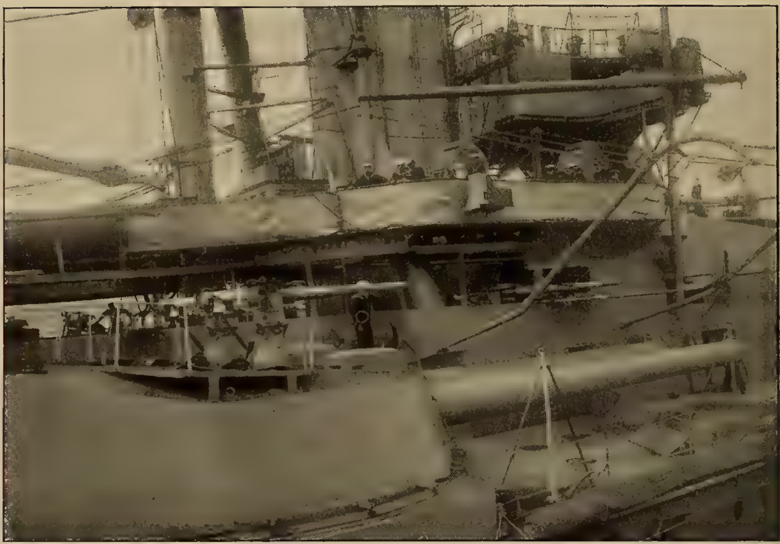
tries. That may be the case, but it must be borne in mind that at the time of which the right honourable gentleman speaks, there was only one considerable naval power in Europe, while the feature of the present situation is that there are now not one or two, but four or five nations which are spending largely on their naval armaments."

In forcing Parliament to adopt the naval defense act the country set up for all time a two-power standard of strength—a formula capable, however, of varying interpretations. It is less than twenty years since this revolution in naval policy was effected, but immediately it became incorporated into the national life of the British people. The pressure of public opinion was so irresistible, in view of the continued expansion of the French Navy, that in 1894 Lord Spencer and the Liberal Cabinet were compelled to introduce another naval programme. From the outset they met with the keenest opposition upon the part of Mr. Gladstone and a minority of his colleagues in the Cabinet. Efforts were made to prevail upon the Admiralty to modify their demands, but without success, and at last Mr. Gladstone determined to take the opportunity to retire finally from public life. With Lord Rosebery as Prime Minister, a naval programme was adopted under which in the two years 1894 and 1895 the following men-of-war were laid down:

Seven first-class battleships.
Four first-class cruisers.
Ten second-class cruisers.
Two third-class cruisers.
Two sloops.
Twenty torpedo-boat destroyers.

H. M. S. LORD NELSON

In these two years Lord Spencer rescued the two-power standard by courageously utilizing the unparal-



GUNS AND SIGNALING BRIDGE OF THE DREADNOUGHT

leled shipbuilding resources of the country. But for the firm stand which he then took, supported by sea lords the present Admirals of the fleet, Sir Frederick Richards, Lord Walter Kerr, Sir John Fisher and Admiral Sir Gerard Noel, England would have never achieved the fruits of the policy which began with the naval agitations of 1884 and 1888, in which Lord Charles Beresford took such a leading part. By his courageous policy Lord Spencer finally convinced the French Government that, whatever party might be in office, the two-power standard of strength would be maintained. From 1889 to 1895 the struggle which was waged was a fierce and costly one. There were not wanting many leading politicians who endeavoured to divert the British Government from its determination to stand by this principle of naval policy. They refused to capitulate, and from that date of Lord Spencer's unparalleled programme France abandoned her effort to maintain a fleet of corresponding or even greater strength to that of Great Britain. At this period the French fleet was not only second in the world, but it had no other rival. The Russian Navy was comparatively small. Italy as a naval Power was already beginning to decline, and Germany was devoting to her naval defenses only three or four millions a year—about half the sum which Great Britain was spending upon new construction alone.

In view of the renewed contest for naval power which has now been begun by Germany, with her rapid succession of navy acts, it must be consoling to the British people to recall the success with which the two-power standard was defended when the last great struggle occurred. Great Britain then showed by the financial and industrial coup embodied in Lord Spencer's programme of 1894 and 1895 the value which the British people attached to the two-power standard and the sacrifices which they were prepared to make in the face of the most determined rivalry. From the time when Lord Spencer announced his great scheme of shipbuilding the rapid increase of French expenditure ceased. In 1894 France devoted to her fleet £10,-821,500, and in the present year the outlay is estimated at less than two millions more, in spite of the incite-

ment to increased estimates to which she has been exposed owing to the expansion of the German fleet. In the same period the British Navy estimates have increased from £17,667,008 to £32,319,500. On the face of it this appears to be a colossal growth in the cost of the British fleet, but we have not far to look for an explanation. No sooner had French rivalry been quashed than Russia elaborated her Far Eastern policy and began to expand her Pacific fleet contemporaneously with Dardanelles) in the Mediterranean, and the large naval forces which were being maintained on an increasing scale in the Far East by Russia, Germany and France in the belief that the Chinese Empire was about to break up and that in a contest for the pieces profitable morsels might be picked up.

At this period Russia had already in Chinese waters seven battleships nine cruisers and a large number of smaller ships—a greater squadron than that of Great Britain. But for

TWELVE-INCH GUNS OF THE DREADNOUGHT CLEARED FOR ACTION

the Emperor William's preaching of the "blue-water gospel" to the States composing the German Empire. Thus it happened that for a series of years the British Government was face to face with the French Navy, upon which from eleven to twelve millions were being spent, and the rapidly-growing naval forces of Russia and Germany. During these years the duty was forced upon the British Admiralty of simultaneous watch and ward against three powerful fleets—Germany and Russia in the Baltic, France and Russia (it being believed at that time that the Russian Black Sea fleet might break through the the development of the Russian and German fleets during this period, the British Navy estimates from 1895 to the outbreak of the war in the Far East would not have exceeded about twenty-five millions, whereas they eventually reached thirty-six and three-quarter millions owing to the varied dangers to which British interests were exposed at a time when British relations with France and Russia in alliance (with Germany, at the head of the Triple Alliance in the background) were far from cordial.

The British people have now entered upon a further stage in the

rivalry of naval armaments under circumstances which are frequently exaggerated. As has been already stated, in 1888 the British fleet was barely equal to that of France alone, and when French rivalry was effectually checked the British Admiralty were faced by the naval forces of France, Russia and Germany. Russia has for the time being fallen out of the competition. This is due not merely to the heavy losses which she incurred during the struggle with Japan — seven battleships, besides cruisers, gunboats and torpedo craft— but primarily to the light which this war threw upon the character of the Russian naval administration ashore and the lack of efficiency of the personnel afloat. In these circumstances the task which faces the British Government in maintaining the two-power standard is not so titanic as is generally supposed. The Russian fleet no longer exists; France, from England's bitterest foe, has become her close friend, and an alliance with Japan will exist until 1915, while British relations with the United States continue to grow in cordiality. In these circumstances an opportunity now occurs for the British Government to repeat the successful policy which was adopted by Lord George Hamilton and Lord Spencer in meeting the rivalry of France, which was no less redoubtable than that of Germany to-day.

H. M. S. BLACK PRINCE. NEW TYPE OF FIRST-CLASS BRITISH CRUISER. THAMES IRON WORKS, LONDON

It is impossible to ignore the progress which has already been made in Germany in expanding the fleet. Avoiding the political aspects of this movement, the rapidity with which it has gone forward cannot, perhaps, be indicated better than by recalling the rapid increase in the expenditure which has occurred in the past twenty years:

DESTROYER FLOTILLA RETURNING TO HARBOUR

GERMANY, TOTAL NAVAL EXPENDITURE

Year	
1889	£3,610,000
1890	4,439,057
1891	4,694,039
1892	4,705,570
1893	4,446,500
1894	3,696,000
1895	4,084,000
1896	4,313,000
1897	5,753,000
1898	5,972,000
Total	£45,803,666
Average	£4,580,366
Year	
1899	£6,486,000
1900	7,600,000
1901	9,629,000
1902	10,454,000
1903	10,257,000
1904	10,568,000
1905	11,425,000
1906	12,006,000
1907	13,624,000
1908	16,601,000
Total	£108,650,000
Average	£10,865,000

This growth in the outlay on the German fleet has resulted from the passing of a series of acts for increasing the strength of the navy. The first of these measures was passed in 1898, and was comparatively modest in dimensions; but in 1900 the aims and aspirations of Germany had grown, and in the act of this year it was decided to provide a fleet consisting of thirty-eight battleships, fourteen large cruisers, thirty-eight small cruisers and a large number of torpedo craft. This did not mark the limit of German ambition, and in 1906 an amending act was introduced, and again in the present year a further amendment was made increasing the number, size and power of the battleships and providing for additional battleship-cruisers of the *Indomitable* type, apart from additional torpedo-boat destroyers. These two measures compare thus:

LAW OF 1900 AND NOVELLE, 1906

	Battle-ships	Large Cruisers	Small Cruisers
1908	2	1	2
1909	2	1	2
1910	2	1	2
1911	1	1	2
1912	1	2	2
1913	1	1	2
1914	1	1	2
1915	1	1	2
1916	1	1	2
1917	1	..	2
	14	10	20

AMENDED LAW, 1908

	Battle-ships	Large Cruisers	Small Cruisers
1908	3	1*	2
1909	3	1*	2
1910	3	1*	2
1911	2 + 1*	1*	2
1912	1	1	2
1913	1	1	2
1914	1	1	?
1915	1	1	2
1916	1	1	2
1917	1	1	1 + 1*
	18	10	20

* Additional ships.

[The German fleet in virtue of this act will include in 1920 thirty-eight battleships less than twenty years old, twenty large cruisers (including ten of the *Indomitable* type), thirty-eight smaller cruisers and 144 destroyers (less than twelve years old). Torpedo craft are not included in the act, but destroyers are being built at the rate of twelve a year.]

The significance of the latest amendment of the German Navy act is not completely revealed in this summary. In the act of 1908 Germany definitely abandoned the construction of medium-sized battleships and armoured cruisers and adopted the *Dreadnought* and *Indomitable* design, thus asserting her determination to rival the British fleet in the character of the ships to be built. This change of naval policy necessarily led to a revision of the sums specified in the early acts for the expansion of the fleet during future years, and German naval expenditure, which now amounts to £16,600,000, will automatically increase until high-water mark is reached in 1911, when the cost will exceed £23,000,000.

The position may be thus summarized:

(a) Germany, down to ten years ago, maintained a small fleet consisting exclusively of vessels intended for coast defense.

(b) Between 1898 and the present year she has been adding to her navy battleships of medium size, provided with heavy armaments and good protection, but deficient in coal supply, and therefore of limited radius of action.

(c) Under the act of the present year she has definitely abandoned these medium-sized ships. Her battleship design has been increased from 13,000 tons to 18,000 tons and upwards. The same movement to increase size and power marks her designs for armoured cruisers, scouts and torpedo craft, and she is now definitely embarking upon the construction of submarines. This year she is spending nearly as much as Great Britain on shipbuilding, namely, £8,366,438.

Germany has thus emerged as a first-class naval Power, and is providing herself with vessels of the largest size, able to go anywhere and do anything. It was not until this latest act was passed by Germany this spring that public opinion in the United Kingdom paid any special attention to naval developments on the other side of the North Sea, because it was realized that, as long as she stopped short of rivalry with the British fleet, her navy was her own business. Now, however, in view of the character of the ships which are being built and their number and the money being devoted to new constructions, an irresistible movement has arisen in favour of a higher standard of naval defense for the United Kingdom so as to safeguard her against the large fleet which is being provided by Germany.

The pathway which the British people must tread if they would maintain their naval strength is easier than appears at first sight, because for the time being the Russian Navy has ceased to be of importance, while the British relations with France are increasingly cordial. In these circumstances a demand has arisen that the British fleet in future should be maintained on a two-to-one scale as compared with Germany. This means a considerable expansion of the shipbuilding programme in the next four years, but there is no apparent reason why the estimates should rise above forty millions sterling, at which they stood as recently as 1904. If the government of the day had the courage to regularize their expenditure on ship construction for four years by means of a definite programme calculated on a two-to-one basis, there is no reason why the British Navy should not in 1914 be on a two-to-one basis as compared to Germany in battleships, and on a yet higher standard in smaller vessels, primarily intended for showing the flag and defending commerce.

In these circumstances the British Navy estimates next year and in the three following years would amount to about £40,000,000, and it is yet to be shown, in spite of other demands on the British treasury, that this is a scale of expenditure which cannot be reached without undue hardship.

The two-to-one standard is a new development of the two-power standard, but it has much to commend it to the British people in that it fits the circumstances of the moment and ensures a superiority of naval strength to provide for such a kaleidoscopic change in foreign relations as may occur at any time in the immediate future.

The salient fact which is revealed by the most cursory study of the history of the British two-power standard is that it has continually varied in accordance with the international situation and the activity of other nations. At one time it has been equivalent to the strength of one navy with a margin over to provide against intervention of another and comparatively weak sea Power; at another it has been held to bind the country to actual equality with the next two strongest Powers; later it was expanded into equality with the next two greatest Powers with a margin of 10 per cent. over for contingencies; and now the most extreme advocates of a big navy in England are content to advocate a standard of two-to-one against Germany, which is lower than the two-power standard which it would supersede. At the same time, this British formula, varied as it has always been with reference to battleships, has always been held not to apply to cruisers required for commerce protection. All the representatives of the Admiralty have always expressed this view. Great Britain owns about 55 per cent. of the merchant ships in all the world's seas, and this superiority of commercial strength and consequent increased liability in time of war has always been claimed as an excuse for provision for commerce protection considerably above the two-power standard. If this claim is admitted by the British people, it is impossible for

THE DECK OF THE DREADNOUGHT, LOOKING FORWARD

them to deny the right of Germany, with her increasing over-sea commerce, also to extend the means for defending it. But in view of the present great superiority in ships for commerce protection which England possesses and the urgency of expenditure upon large armoured ships which is already in view, it may well be that the Admiralty will, in the next four years, keep their demands for ships for the defense of commerce down to the lowest possible limit, postponing this form of expenditure until the present acute situation in armoured ships has passed away five or six years hence and the race for naval power is checked, as seems to be inevitable, by the financial pressure exerted by the taxpayers of European Powers.

It cannot be forgotten that, while in Great Britain the outlay upon the navy and a voluntary army is the sole contribution of the vast majority of the population to purposes of defense, in European States the male population are compelled to render personal service in addition. They are bearing, consequently, a threefold burden, which in Germany is excessively heavy. The people of the German Empire are contributing upwards of sixty millions sterling annually to the maintenance of the navy and army, and, in addition, they have to conform to a severe conscriptive system. The population in Germany is about sixteen million greater than that of the United Kingdom; but nevertheless the pressure of enforced service and high taxation for defensive purposes is becoming excessively burdensome, and for this reason, if for no other, it may be hoped that when the second period covered by the German navy act opens in 1912 there will be no attempt to expand the comparatively modest programmes which are specified for the last six years of the term of ten years covered by this measure. If this proves to be the case, the naval crisis in England, of which so much is now heard, will be of comparatively short duration. After five or six years of expenditure at about forty millions annually the estimates will automatically decline, leaving the relative strength of Great Britain in contrast with other Powers very much as it is to-day.

POSTSCRIPT

It may be asked, and the question is quite natural in the circumstances, "Is the British fleet up to the two-power standard as it exists at present?" Well, the facts cannot be set forth more simply than by taking the completed armoured ships of less than twenty-five years under the British flag and comparing them with the vessels of corresponding age in the fleets of Germany and France, which for the present are the two Powers of the two-power standard:

BATTLESHIPS

Displacement	Britain	France	Germany
Over 16,000 tons........	11	..	..
14,000 tons or over.....	30	6	..
Over 13,000 tons........	..	..	5
Over 12,000 tons........	7	2	5
Over 11,000 tons........	4	8	5
Over 10,000 tons........	7	5	5
Under 10,000 tons.......	..	..	4
	59	21	24

ARMOURED CRUISERS

Displacement	Britain	France	Germany
Over 16,000 tons (Indomitables)	3	..	..
14,000 tons or over.....	3	..	..
12,000 tons and over....	16	5	..
Under 12,000 tons.......	16	15	8
	38	20	8

From these figures it will be seen that in the largest completed armoured ships the British fleet is above the two-power standard. The German battleships of under 10,000 tons are obsolete, and many of those between 11,000 and 12,000 tons in all three fleets are of little account.

THE NAVAL POLICY OF GERMANY, ITS PROGRESS AND AIMS

By Count Ernst von Reventlow

THE naval policy of the German Empire, according to my idea, is often misunderstood by foreigners, because it has not yet a history of its own. It is new, and anything new evokes criticism; hence the newly formed policy of the German Empire in 1871 was regarded with mistrust. It was looked upon as a forerunner of further warfare, upon which it was considered to be dependent for its origin and existence. This opinion was chiefly due to the preconceived idea that moderation is a human virtue but seldom met. Even the great Napoleon, with all his genius, owed his downfall to the fact that he could not act with moderation. It is now nearly forty years since the formation of the new German Empire, and the world must surely now understand that its policy at home is an essentially peaceful one. As Macchiavelli says, a State can only be upheld by the same means by which it was formed, so we must understand to-day that the German Empire would soon come to grief if it neglected its defenses; but by no means that it needs war in order to maintain its position. Germany has now for some time begun to build up its hitherto neglected fleet, and to perfect its organization. Other powers, especially England, have perceived in this a warlike intention and a cause for international disquietude. The following observations may perhaps serve to dispel this prejudice. I should like first to point out that I am far from repeating the phrase: an army or a fleet is needed and made *solely* to keep peace. Such expressions may be useful sometimes as sentiments, but they are in themselves untrue. Certainly, while no large country to-day wishes for war, it is a perversion to say that the instrument of war exists only for the sake of peace. One takes up arms in order to protect one's life and property: by peaceful means if possible; if not, by war. Therefore all preparations for war must be carried out with the object of insuring a military success. What is understood by success depends upon the nature and requirements of each individual country, as well as the power and policy of presumable adversaries and their possible armaments.

A recent national economist maintains that, under existing circumstances, the word property means that a certain portion of the earth's surface must belong to every inhabitant of a country. This statement contains a profound truth, but it must not be taken literally. By property in this sense must be understood the sphere of activity created by individual effort. It may be in agriculture; or, less directly, in industrial pursuits, which occupy thousands of workers. Primarily in commerce and all trades, it lies in the home market. Its importance is underestimated, particularly in Germany, in the United States of America, and also in England herself. It is a sign of the times that a man like Carnegie, in a short essay, has brought to our notice the fundamental importance of the home market. These considerations appear to have little to do with the naval policy of the German Empire, but they form the economic-political basis for the remarks which follow.

I am quite convinced that the economic basis of the German Empire must always lie in the improvement of the home market, if the German Empire is to remain sound. This, in Germany, we call the home-policy, in opposition to the world-policy, which would be ineffective if it lost its contact with the soil, like the giant Antæus. The term "world-policy" is one of those unlucky expressions which have caused endless misunderstandings in all parts of the world. From the German viewpoint the term world-policy means that the German Empire accepts geographical expansion on the Continent as barred; on the other hand, its population is increasing yearly, at the rate of not less than a million people. This increase began after the formation of the Empire, when political security and the wise internal policy of Bismarck awoke great economic activity and developed an almost unexampled progress. Some decades ago, a hundred thousand Germans emigrated yearly to other countries, because they could not, or believed they could not, secure the means of subsistence in their own country proportional to their abilities and hopes. These men were certainly not the least patriotic of Germans, yet they were lost to the German nation, because Germany possessed no colonies and had not the power to acquire any, nor to extend the boundaries of the German Empire. If we do not wish that a similar contingency should arise to-day, it is due to the growth of a German national feeling, based upon both economic and military considerations; for, considered from either of these standpoints, the German nation loses some of its power with every German emigrant. We, therefore, wish to keep every citizen, and this naturally becomes more difficult as the population increases. Not long ago it was estimated at 40,000,000 people; it is now more than 50,000,000, and it will not be long before the German Empire, which has not been expanding proportionally in area, will have to maintain 80,000,000. This is the real basis of both the home and the foreign policy. It is easy to perceive that the growth of the population cannot be wholly met by a development in agriculture, the mainstay of the home market. This forms the basis of the system, but does not suffice even now, and will in the future suffice still less. We find this condition already in England, its counterpart in France, and a more harmonious proportion in the United States. For these reasons Germany has to import largely from abroad, and this necessity is the greater because the country lacks in mineral wealth; coal, iron, and potash are its chief products. Industrial imports will thus always remain greater than the exports, and increase at a more rapid rate. This is an unfortunate state of affairs, because Germany is, not like England, a creditor State. The home trade cannot balance this deficit if, at the same time, the ratio of exports diminishes. To-day, about 17,000,000 Germans get their living from industrial occupations and everything connected with them. Industry depends just as much on imports as upon exports, and the other portions of the national activity are directly and indirectly concerned in it to a considerable extent.

The word property may be defined as that which one is in a position to defend. The enforcement of law and the maintenance of order the State provide protection for those inland; the army protects the whole against foreign adversaries; and since it is also the duty of the Government to protect everything German on the high seas, and also to further the extension of property by every possible means, which is only possible by a guarantee of effective protection, together with a good economic policy, it is therefore an incorrect supposition to assume that because our coast line is small, we need no large fleet to guard it. The

actual geographical length of the coast is a secondary matter compared with the value of that which goes out from these coasts and comes in, and with the possible developments from these coasts over the ocean. If Germany had no great extent of coast, but only one small harbour from which to negotiate the whole of its present and future trade, it would not be necessary to make much alteration in its fleet.

These facts have only lately been recognized in Germany, which is easily explained by reference to German history. Great changes are not grasped at once by the majority, but only when they forcibly obtrude themselves. Great Britain forms a striking exception to this general rule. Of course England has been forced to this knowledge by nature; she has been a seafaring nation for centuries, and the English seem to understand by instinct what the Germans have grasped but recently and learned but slowly. There is, however, no reason why the German nation, having once arrived at this conclusion, should hesitate to commence immediately the construction of a first-class fleet. The longer a thing has been neglected, the quicker it should be rectified, and the greater the efforts exerted for its rectification.

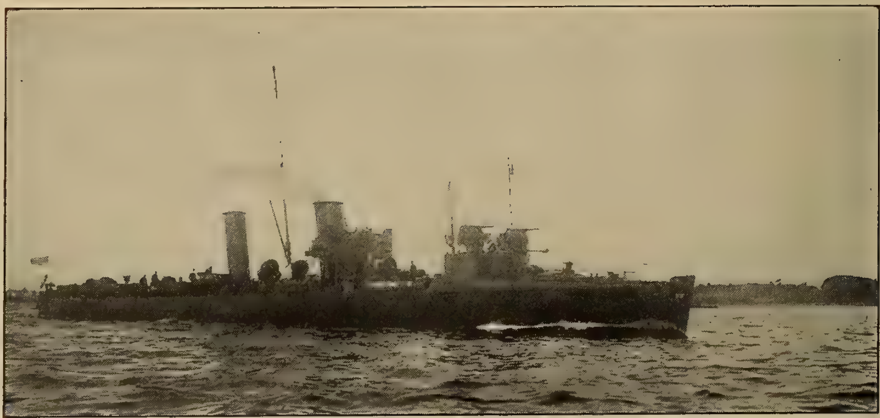
About ten years ago an English newspaper said: "*Germaniam esse delendam;* in former centuries war was often carried on for years about one single town; why should not to-day war be carried on about a commerce which involves millions? If Germany disappeared to-day from the surface of the earth there would not to-morrow be one Englishman who would not have become richer; on the day after the beginning of hostilities the German ships would be at the bottom of the sea, and England would say to the other countries: Take what you like in Germany." In Germany such expressions naturally excited the realization of the inadequacy of the country's defenses to the highest pitch. They were repeated in later years; namely, in 1904 and 1905, and aided materially in the understanding of the necessity for naval defense in Germany. At that time, in the year 1900, the German Navy was really a negligible quantity, and England was quite right in her estimation of it. In the ten years before 1900 the possibility of a naval war never occurred to the German people; the majority of them had not comprehended the growth of our naval interests.

It is no wonder that the development of the navy had been hindered through long neglect, and that in the nineties it was in a very incomplete state. Until the year 1888 generals stood at the head of the navy, a fact that to-day, only twenty years later, seems quite inconceivable. The accession of Kaiser Wilhelm II. brought in a new era. One of his first actions was to place an admiral at the head of the navy. The untiring energy of the Emperor is too well known to need any mention from me. Less well known, however, is the fact that at the commencement of the nineties the activity of one man began to make itself widely felt—a man who now for eleven years has occupied the first place in the German Navy as State Secretary of the Imperial Marine Office, Admiral von Tirpitz. This able organizer had already, as one of the younger captains, practically created the torpedo flotilla, and thereby shown a far-sightedness which is still apparent to-day, insomuch as his opinions at that time have been much later recognized as correct by other navies. In the first half of the nineties he was head of the staff, at that time having supreme command of the navy. During that period he laid down theoretically the foundations of the navy bills, which were proved practical in the spring manœuvres, but which did not obtain acceptance until several years later. The so-called autumn manœuvres in the early part of the

nineties were much ridiculed by the foreign Powers. They reminded one very much of Falstaff's celebrated recruits. There appeared an ancient ironclad, which was built in the sixties, also the "floating gymnasiums," or training frigates, which tried to make a warlike appearance. The small coast-defense ships of the *Siegfried* type, new as they were, were recognized as failures, while the collection was rounded up by the old gunboats and the so-called "flat irons" of the *Sachsen* class and the "artillery museum" *Mars*. The only vessel worthy of the name of battleship was the *Worth*, which at that time was quite new.

Meanwhile, the State Secretary of the Imperial Marine Office, Hollmann, conducted year by year an ineffective contest with the German Imperial Diet concerning the execution of the German Emperor's plans. This lasted until the year 1897, when Hollmann retired and Tirpitz succeeded him in office. In the winter of the same year the first naval bill was laid before the Imperial Diet and passed by a small majority. Two years later the Diet passed the second navy bill with a larger majority.

The advantages gained by these naval programmes have been the subject of many discussions, and will probably continue to attract attention in the future. Like every law made by mankind, they have their deficiencies—they are certainly not perfect. England requires no special act to keep its navy up to the mark; in England such a thing might be a hindrance to the development of her naval policy. For Germany it was most necessary to remove the subject of the construction of the fleet from the arbitrariness of the Imperial Diet. We can remember a time when the request for a single cruiser was discussed for months and finally refused; one battleship, the *Oldenburg*, had to be built nearly a thousand tons smaller than was intended because the Imperial Diet crossed off some millions from the sum needed for its construction. At that time both inclination and understanding of the matter were lacking. The fleet was a subject for sport and pleasure, and the naval programme managed from the standpoint of a petty clerk. In judging these things it must not be forgotten that at that time we actually did not possess even a small fleet of any value, but that nearly everything had to be made from the beginning. If the aim of the Emperor and of the State Secretary of the Imperial Marine Office was to be attained, the foundations of the organization first of all had to be firmly laid, and the *esprit de suite*, as



S. M. TORPEDO BOAT DESTROYER "D 10"

the French say, guaranteed. In addition, there were purely technical considerations. The German shipyards had until then received very few orders, and both for them and for the ordnance and armour-plate industries it was necessary to give assurances for future work. The naval programme for the year 1898 set forth the required fleet at seventeen battleships and eight coast-defense vessels (which were already in existence). The achievement of this programme was slow and the accomplishment of these aims required eight years. To-day, when we look back on this bill, it is clear that it can only be considered as a trial; it signified that first step—the one which always presents the greatest difficulty. That the second bill came only two years later and that the strength of the navy was fixed at thirty-eight battleships was not due to a change of policy, but to the fact that the State Secretary, thanks to his clever explanations in public and his no less clever tactics in Parliament, made the possibility of fully carrying out his plans evident. Further, it was proved that the German shipbuilding industry was quite capable of undertaking larger orders if they could safely count on a permanent and regular policy. The German public was kept informed of the beginning and rapid development of the German naval interests by a number of statistical and other publications. The newly-formed German Navy League now began to display its powerful influence. All those elementary facts which seem a matter of course to every Englishman began to take root in the German nation.

The second navy bill, which the Imperial Diet granted in the year 1900, still forms to-day the basis of the German naval policy. It fixes the number of battleships at thirty-eight, forming four squadrons of eight ships each, two flagships and four battleships as a so-called reserve force; also eight armoured cruisers for the home fleet and two as reserve, while three for foreign service, with one as reserve, were taken into consideration. Of small cruisers, twenty-four were intended for the home and ten for foreign service, with four as reserve. Admiral von Tirpitz explained to the Diet and in the preamble of the naval act, as the necessity for this increase in the size of the fleet, that Germany had to be in a position to protect its coasts and foreign trade, and, furthermore, to be in such a position that the greatest sea Power would hesitate before attacking her, for fear of losing her dominant naval position. These plain words were much discussed in England, and, strange to say, they even now are often used to show that Germany intended to prepare for war against England. It is understood, of course, that by the greatest sea Power is meant England.

The real line of thought is: we are not in a position to build a fleet as large as England's, nor do we think of doing so. When creating or planning a means of defense, in measuring its strength all possible adversaries must be taken into consideration. England, the greatest naval Power, is naturally among these possible adversaries. We shall never be equal to her, for we know that England has possessions and interests to defend all over the world. If, however, we brought our navy to such a standard that a war with us would cost England so many ships that she would not be able to protect her interests elsewhere as heretofore, then we should feel satisfied that England would not attack us. I think this is a programme which clearly shows its purely defensive character; it is the programme of the weak, who know that they are far from ever attaining England's naval strength, and, therefore, are reasonable enough to content themselves with what they believe they are capable of achieving. It seems strange that this proposition could excite so much agitation in England. If a continental nation plans its military programme to ac-

S. M. S. KAISER BARBAROSSA AFTER ALTERATIONS. (KAISER CLASS)

cord with the strength of some other Power, if a new gun or new field cannon is immediately introduced when it is realized that the old ones are not as good as those of a possible enemy, no one is troubled about it. But when Germany made known her decision to render her fleet so strong that England would not care to attack her, that was taken as a menace.

The statement that we merely wanted peace and that we constructed a fleet solely in order to keep the peace with England under all circumstances, expresses a principle which I have already pointed out as decidedly incorrect. I find myself opposed to the official view in this respect when I say that Germany, under all circumstances, must create a coast-defense fleet and a high-sea fleet which together shall be capable of averting an English attack. The argument for the navy bill differs in so far that it deals only with the English consideration: the English fleet in an engagement with us might be weakened more than desirable for Great Britain's world-policy.

The navy bill of 1900 provided for a period of sixteen years. Two battleships and one armoured cruiser were to be put on the stocks each year, also six torpedo boats, which were not really included in the bill, but had to be granted every year; the construction of the first ships under this bill began in the year 1901. Of finished battleships at that time the German Navy possessed only four of the *Brandenburg* class and one of the *Kaiser* class, five ships, while the three ships of the *Wittelsbach* class were still in course of construction. The previous irregularity and want of military clearness had up to the present time a very bad influence on the shipbuilding policy. The *Brandenburg* class was in service at the end of the eighties. This vessel was the first German specimen of the heavy fighting ship; it possesses six 28-centimetre guns, placed in three turrets situated amidships, and was practically a forerunner of the *Dreadnought*. Its principal fault lay in its imperfect armoured defense, the too great height and the lack of medium-sized guns. There are at the same time many good points in this class of ship, and it is a pity that it has not been improved in the fol-

S. M. S. SCHLESWIG-HOLSTEIN. (DEUTSCHLAND CLASS)

lowing types. Instead of this, they went to the other extreme with the *Kaiser* class. That received four 24-centimetre guns and eighteen 15-centimetre guns. This was the period when the value of the rapid-firing, medium-sized guns was overestimated. Since the battle of Tsushima this mistake does not appear to us so great as before, but the neglect of a sufficient armoured defense is all the greater. It was desired to present a very large offensive force on a small displacement, and therefore the defensive had to be neglected; to-day the *Kaiser* class is being rebuilt so that it may be high in the water, and some of the 15-centimetre guns have been taken out. The *Wittelsbach* class carries the same armament, but the medium-size guns are arranged more serviceably and the armoured defense is better.

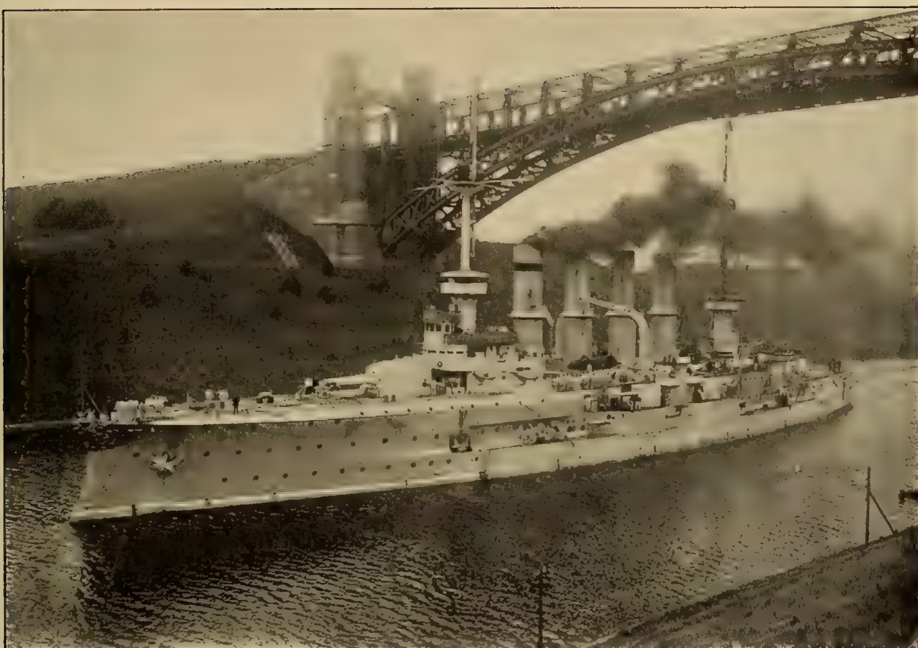
The first construction under the new navy bill were the five ships of the *Braunschweig* class, and following them the five *Deutschlands*. They each have an armament of four 28-centimetre guns and fourteen 17-centimetre guns, and the armour belt

MARINE REVIEW; BATTLESHIP OF DEUTSCHLAND CLASS

is almost complete. They are, on the whole, good ships, whose only defect lies in the smallness of their displacements. With the *Braunschweig* class the German shipbuilding and construction department showed its capability to build good battleships. The chief fault is, as has been said, their lack of size, and this was due to the money question. This was purposely limited at that time to meet the views of the German Diet. The State Secretary of the Royal Marine Office wished, above all things, to get the organized navy bill accepted. He considered it of the highest importance that the minimum number of ships in the new German Navy should be fixed under all circumstances and for all time. He knew, on the other hand, that the German Diet would not go above a certain sum, and so he may have thought: first get the number of ships safely secured and then the other matters will follow later. Besides, opinions were still so divided in different navies that it was doubtful which was the better plan, numerical strength in ships or individual strength of a single ship. The American authority, Mahan, some years later held that a large number of ships of medium displacement were more advantageous for a navy than a small number of very large ships. In any case, the *Braunschweig* class was good at the time when the class was planned, and also for some years after; the displacement has been most excellently utilized by the builders. At the same time England put her *King Edward* class on the stocks and soon after the *Nelson* class. We already felt doubtful about the *King Edward* class. Though it had many drawbacks (and especially as it was not yet completed), some doubts were entertained, which have since been realized in the turrets of the *Indomitable* class. It was clear that England was increasing the displacements of her battleships, and consequently their individual strength, while Germany, on her side, could not take the alternative which Mahan indicated, namely, to put on the stocks a correspondingly larger number of medium-sized ships. For these reasons an agitation began in Germany for larger displacements after one for the increase in the number of ships had met with no success. It was largely believed in England that this new agitation was caused or supported by the party in office. That, however, was not the case; they were really opposed to the policy of the Imperial Marine Office.

The aim of the agitation was attained in the winter of 1905, when the Imperial Marine Office agreed to the demands and promised in future that all ships built should be individually equal to those of other nations. This was foreseen as inevitable. It is illogical to build ships as weapons of war which are weaker than those of other nations. The only possible way in which this could be done with any success would be if an extra number of small ships were built, provided it were proved that small ships in large numbers could equal a smaller number of ships of greater strength. The idea is naturally misleading, especially for weaker navies; it reminds us of the old fallacy that by means of a trick more can be accomplished, at less cost, than by a more powerful enemy. One forgets the old strategical rule that we should always credit our enemies and competitors with being clever, and not to believe that we alone are the unassailable parties. On this principle the agitators for increase of displacement of our ships have in their time used the increase in British vessels as a substantial proof. We saw that the difference in strength between the German and English classes became continually greater. This relation could not be altered by an occasional increase of displacement, but only through the introduction of the maxim, hitherto not current in Germany, that in a modern war only the individual strength of the ship can be decisive, and that it

solely constitutes the strength of a squadron. I said before that all this is now a matter of course. But in Germany things were different. The navy bill of 1900 had not only fixed the programme of construction until the year 1917, but also the yearly maximum sum to be entered in the budget. Therefore these sums represent the real and compulsory basis for the yearly requisitions. Naturally the Imperial Diet was satisfied if the sums were not exceeded, but considered it almost as a breach of contract if the appropriations were exceeded by several million marks. This limitation explains, to a certain extent, why in the years between 1901 to 1905 the strength of our battleships was not increased by even one ton, while in England they successfully attained to the *Queen*, the *King Edward*, and the *Nelson* classes, and finally to the *Dreadnought*. The State Secretary of the Imperial Marine Office was perhaps apprehensive lest the opposition in the Imperial Diet might see in a demand for an increase of displacement a breach of the navy bill. The State Secretary rightly considered the bill of such importance that under any circumstances it must be supported. But, on the other hand, he did not recognize that it would have been quite possible to make the Diet change its opinion, just as it was possible in the winter of 1905-6. Political affairs at home and abroad could just as well have come to his help then as they did later. But there was still another reason to be considered. A substantial enlargement of the German battleships and armoured cruisers would require a widening and deepening of the North-East Sea canal, an expense which could not be ignored. This consideration also influenced the Government at first to decline the increase of displacements. When the continuity of the present policy had become quite impossible, and had placed the German fleet at the ridi-



ARMOURED CRUISER YORCK PASSING THROUGH NORTH-EAST SEA CANAL

cule of the world, a slight enlargement of displacements would have been of no use. This, however, is what might have been intended at first, as it has usually been our custom to remain some thousand tons behind the English ships. Fortunately the German Government at the last minute resolved not to make the same old mistake.

To-day it is in the position to provide sums for shipbuilding as the exigencies of the times require. It is very worthy of notice that the attitude of the German Diet just at this time had essentially improved. The proposal of 1905 was accepted without much opposition, and now, in 1908, the Diet, with the exception of the Socialists, unanimously agreed to the still larger demands almost without discussion. So the future status of our ships is fully safeguarded in Parliament. Every increase in size, every new invention, be it ever so costly, will be introduced as soon as possessed by any other Power who might be our enemy, and who might, by an improvement in their ships or an enlargement of their dimensions, gain an advantage over us. The German Diet and German public are of the opinion that Germany must limit the number of ships, and therefore it is all the more important that only the best of ships shall be built. This is only natural; but how foreign countries have agitated themselves about it! That is easily explained; for, especially in England, there had appeared continually in the Press a statement to the effect that the German ships could only have a small fighting value on account of their small displacements; they were treated with contempt, and Jane's "Fighting Ships" shows how they were classified. England was quite right in her criticism, but wrong in her deduction that it must always be so in Germany.

Then England made her great naval-political mistake in building the *Nelsons* and *Dreadnoughts;* it was indeed a political and not a business error. Probably Germany would not have gone over to the present principle of the individual value of ships if England had not put the *Dreadnought* on the stocks. To us, the "Chauvinists and Agitators," the *Dreadnought*. was extremely welcome, like the *Lord Nelson* before her; for in order to support our demands for larger ships we had to place before the nation a comparison of our ships with those of foreign navies. If England had not built these types possibly in the course of time the German ships would have increased a thousand tons, but would still have been less than the British displacements. It was said in England that the increase of displacement showed plainly that Germany was preparing for war with England; in other words, was at enmity with England. An impartial observer must, I think, concede that it would be an act of great stupidity to sacrifice millions on a fleet of inferior ships. If one prepares specifically for war, there are armies and fleets provided, and it is useless to buy a child's sabre when the enemy possesses a real sword. On the other hand, it can reasonably be supposed that England would be pleased as long as Germany built inferior ships.

These considerations show the impracticability of a far-reaching navy bill. Nevertheless, if Germany had not had the bill nothing would have been accomplished. It is doubtless correct that, next to the canal question, the navy bill was the reason why the German naval administration did not sooner increase the displacements of the battleships; but an alteration could have been made in the year 1903 just as well as in 1905. The bill was not at all whollv futile; it effected one improvement, inasmuch as last year a real advantage was obtained, namely, the reduction of the age-limit from twenty-five years to twenty. The idea of a fixed age-limit occurred first in the naval bill of 1898, when the age for

a battleship was twenty-five years and for an armoured and small cruiser twenty years. The age reckoning begins with the sanction of the first instalment, and similarly the instalment of the new replacement-ship is to be asked for when the old ship reaches its limit of usefulness; but as the time for building the new ship has to be allowed for, the substitution does not actually take place after twenty years, but some time later, according to how long it takes to complete the ship under construction. An age limit of twenty-five years really means from the time the design is completed to the completion of the new ship, an age of about thirty years. If the German Navy is required to limit the number of its ships, but at the same time to keep up its quality, then the naval bill of 1900 must also be amended on this point. This improvement, the reduction of the age limit, was introduced in the winter of 1907-08; therefore at present and in future the limit for battleships, ironclads and small cruisers is twenty years.

It is still to be noted that in the winter of 1905 the construction of six armoured cruisers was required at the same time as the increase in the displacements. This was no new demand, as the Imperial Marine Office had already asked for these six ships in the year 1900 for foreign service; they were, however, crossed off, and the State Secretary had declared that he could not do without them, but was willing to postpone the request until 1906. Seven small cruisers, wanted for foreign service, were also refused at that time. Instead of them the State Secretary of the Imperial Marine Office in the year 1905-06 asked for more torpedo boats. Hitherto no age limit had been fixed for these, because sufficient experience had not then been obtained with these newer type boats, but since this knowledge has been gained, the age limit has been fixed at twelve years. At the same time the number of boats has been increased by a third, namely, from sixteen divisions, equal to ninety-six ships, to twenty-four divisions, equal to 144 ships. The development of the naval policy during the last year has shown that the need for torpedo boats was greater and more pressing than for small cruisers. The two factors—the total number and age limit—produce a yearly building quantum of twelve boats.

GERMAN ARMOURED CRUISER GNEISENAU

The numerical strength of the German Navy after the various improvements and alterations has been fixed as follows: Thirty-eight battleships, twenty armoured cruisers, thirty-eight small cruisers, 144 torpedo boats. Of battleships, which are good in themselves, but at the same time too small, we have now ready the ten *Braunchschweigs* and *Deutschlands,* besides the less successful ten *Kaisers* and *Wittelbachs,* and lastly the four antiquated *Brandenburgs.* Of armoured cruisers, there are altogether eight ready, of which two, namely, the *Scharnhorst* and *Gneisenau,* may be said to have been very successful in their way. The older ones are partly too small and less successful. Of small modern cruisers, twenty-one are ready and belong to the same class as the *Gazelle,* which was launched in 1898. This class has proved itself very good, and we may rest contented that, contrary to other nations, we have developed the small new protected cruiser with success.

There are now in course of construction seven battleships of the large, new class of the years 1906, 1907 and 1908, three new large armoured cruisers and six small cruisers. Nothing of the class and armament of these ships has been made public.

By reason of the reduction of the period of utilization for battleships to twenty years the construction programme had to be somewhat altered, as, until 1917, three battleships became renewable at an earlier date. The putting of these new battleships on the stocks had to be commenced yearly. There is still remaining a so-called increase of construction from the bill of 1900, and this will be added at a convenient time in one of the following years. If no further alterations occur in the building plans the regular construction of two battleships and an armoured cruiser yearly, with small variations, will be regulated automatically. In this automatic renewal lies the great value of the navy bill. As in the case of torpedo boats, it regulates itself alone by the two factors—number of ships and age-limit replacements.

Of course, this can only be correct as long as the determined number of ships is considered sufficient. The Chauvinists and Pan-Germanen in Germany, to whom the writer of these lines belongs, are of the following opinion: In former years the navy had been much neglected, and until 1905 battleships were put on the stocks which were too small in comparison with those of other nations to fulfill the duties of battleships. This drawback vanished in 1905, and the ships built from that date will be good and valuable. Thereby appears the logic of Germany's necessity to build as quickly and to put as many ships on the stocks per year as possible. No one can foresee the development of political relations; but the quicker we build, the better we shall be prepared against an attack and other eventualities. By the reduction of the age limit an extra battleship will be put on the stocks every year for three years. But that must not be considered enough. Besides, it is known that the German shipbuilding yards, as well as the gun and armour-plate industries, are capable of a far larger production. Only on the condition that the completion of the navy is really effected quickly can the legally fixed united strength be considered sufficient. If we Chauvinists go on working with this aim it is certainly not prompted by enmity against England, but by the wish that Germany, as soon as possible, should be equal to any eventualities at sea as well as on land. We must also take into consideration the fact that the navy, like the army, is not only a military, but also a political tool. England owes her successful policy, for the most part, to the cleverness of her King and of her statesmen, but without the strength of her navy the same results would

not have been achieved. If France, Spain and Russia were not weaker than England in a military sense they would not have entered into agreements and *ententes* with her. Had Germany two years ago had the navy which the bill of 1900 has planned the Morocco policy would have been differently arranged.

We are not afraid of England attacking us, and if at any time English admirals and politicians advised a preventive war against Germany that time has now passed. If England did it now or in years to come, she could not recoup herself for her losses. Naturally, it would be an easy matter for the English Navy to close the Channel and the arm of sea between Scotland and Norway, and thereby choke the sea trade for Germany by blockading the North Sea. The monetary loss to Germany would be enormous; but the needs of the population could be supplied for a long time from within, besides which Germany has the power to do the same thing on continental waters. Our coasts could be made inaccessible by the use of numbers of sea mines, together with torpedo boats and submarines. With this protection our high-sea fleet would remain intact and await a favourable opportunity. The war would be a long one, and the English fleet would suffer too great a loss if they tried to force their way through the mined waters to our harbours and seaports. The greatness of this loss would also indirectly affect the condition of Great Britain's foreign possessions to a high degree and weaken her *ententes* in Europe. It is certain that a temporary loss of trade would be too great for Germany to wish for such a war, but the idea is regarded calmly. He who, in England, thinks a war with Germany would be desirable and advantageous reckons wrongly. Indeed, one can go so far as to say that, taking the direct and indirect consequences of such a war into consideration, England would risk more than Germany.

THE GERMAN HIGH-SEA FLEET SALUTING

I have tried to impress, at the beginning, the fact that the increase of the German population and our rapid economic development force us to exercise an economic world-policy. This necessity must continue to increase, because the area of the German Empire does not increase in proportion. The foreign policy of all nations having a growing industrial population must be grounded upon an economic basis. To ensure industrial prosperity military and naval power is necessary, and without it diplomacy cannot work with success. The rapid and still increasing industrial development of Germany makes peace desirable. On the other hand, we and the largest portion of the German nation are of the opinion that it would not only be an undignified position but also a great piece of political stupidity to yield to any political pressure from abroad which would hinder our freedom of movement economically and to attempt to force us into an international position which is not in keeping with our strength.

The quicker the German Navy is brought to its required strength, the surer it is that other nations will avoid entering into such dangerous situations.

THE EDUCATION OF A MARINE ENGINEER

By Professor W. E. Dalby, M. Inst. C. E.

THE term marine engineer may be used to designate either an engineer in charge of engines afloat, or in a fuller technical sense, an engineer who is capable of designing a marine engine complete in every detail. The designing engineer should be capable of fixing the power required to drive a ship of given lines and displacement at a specified speed; of determining the best type of engine and the best type of boiler to be used for the purpose; he should be able to specify all the leading dimensions of both engine and boiler, and should then be able to make, or superintend the making, of detail drawings of every part, both of the main engines and of the auxiliaries; his knowledge of the art of design should enable him to fix the size of the several parts, so that whilst there is no redundant material there is no danger of a breakdown or of the failure of the smallest part; his design should be such that, whilst conforming to all the requirements of strength, reliability and safe working, the cost of manufacture is a minimum.

These requirements are exacting, and a long training is required before a marine engineer is in full possession of the knowledge of engineering science, of engineering practice, and experience in the working and manufacture of engines necessary to enable him to tackle a design with the certainty of gaining approval on the one hand for a good, economical design which enables the speed trials to be satisfactorily accomplished without troubles of hot bearings and the like, and on the other hand of winning the approval of the "chief," whose business it is to handle the engines and watch them from one side of the world to the other. To win this double approval is a difficult matter, and it is not too much to say that a designer who can habitually do both is born, not made. Yet, however great his natural gifts, a proper training will considerably enhance their value, and the object of this paper is to trace out a course for a young man who, before he has left school, even, has made up his mind to be a marine engineer of the first rank, come what will.

What is the best way to begin? If he were desirous of becoming an engineer in His Majesty's navy, the question is completely answered by His Majesty's regulations.

Presuming the preliminary application on his behalf to be successful, in due course he appears before a board of the Admiralty, the members of which ply him with cunning questions on general matters to ascertain if he possesses the qualities of quick observation and mental alertness so necessary to a naval officer. Having satisfied the board on this and other matters, he enters Osborne at the age of 12 and starts on a training devoid of the irksomeness which weighs on his less fortunate brother at the ordinary schools of the country. Briefly, the hours of educational work at Osborne are divided into three nearly equal portions, one being devoted to mathematical and scientific subjects, another to

literary subjects, whilst during the third portion instruction in handicraft is given in a workshop perfectly equipped with the tools and apparatus appertaining to the several departments of a mechanical engineer's establishment. Sports are, of course, not neglected. Thus his brain, his hands, and his eyes are continuously cultivated. Two years at Osborne are followed by more advanced study at Dartmouth, the work still being arranged to develop the natural aptitudes of the boy. The time arrives at last when a choice must be made of the special branch of the service in which he desires to specialize. If it is the engineering branch, then his studies all trend in the direction of his choice.

But the naval engineer is hardly the type which we have in mind in considering the training of a marine engineer. The reference to the Admiralty system is made to show at what an early age the ideal training should begin, in the opinion of the best experts in this country, and to emphasize that the training sketched below is short of the ideal because satisfactory preliminary school education cannot as a rule be found, partly because tradition assigns an inordinate proportion of time to classical studies in the best schools of Great Britain. The training of a youth for marine engineering has generally to be built on a school training, which usually leaves much to be desired.

It may at once be postulated that the training must include shop work, college training, and experience at sea. Which should be taken first, shop work or college course? To a certain extent, this question may be answered from the report on the education and training of engineers issued by the Institution of Civil Engineers, Vol. 166, 1905-06, Part 4, in which it is stated that the practical training should be divided into two parts whenever that arrangement can be made, and that the preliminary stage of practical training should consist in all cases of at least a year spent in mechanical engineering workshops. This introductory workshop course is desirable even when students do not contemplate devoting themselves at a later stage to what is generally designated "mechanical engineering." Assuming that it is possible to arrange for this introductory course, the committee expressed the view that it should not be shorter than one year, nor longer than two years.

There are exceptional cases where it is undesirable to send a boy into a workshop at the age of 16; the matter has a large personal equation in connection with it, and such exceptional cases require special consideration, but there can be no doubt that in the ordinary way a student takes more real interest in his work if he has some knowledge of the practical aspects of engineering, if he has to a large extent unconsciously absorbed the general features of an engineering establishment, and if he knows without explanation that a belt is a means of transmitting power as well as an article for girding up the body; that a drum may mean a kind of revolving wheel as well as an instrument of music; that a jig does not always mean an ancient form of dance, and that a boiler produces steam; that steam drives an engine, and that a pair of jimmywhollapers is an indispensable instrument for certain marking off purposes.

These illustrations may seem to exaggerate the ignorance of a boy with engineering aptitudes, but they do emphasize the truth that the technical language of the profession must be learned in the places where that language is spoken, namely, in the workshops, so that time need not be wasted at college in the teaching of it. Let us agree then that in all cases where it is possible the embryo engineer is sent for a year's preliminary training to a workshop, and in this case there need be no hesitation in the choice of the kind of workshop; it should preferably be that

attached to a shipbuilding yard which includes a department for the manufacture of engines and boilers.

An enthusiastic youth will now find himself in an environment in which his days will be full of interest, and which provokes in him a spirit of eager inquiry which may some time bring him in collision with the powers that be, especially if he is found by the manager studying the arrangement of turbines in the engine room of a boat at the mooring buoys in the river when he ought to be turning boiler stays in the machine shop some half a mile away. He will begin to learn that duty and inclination are not always synonymous terms, and the sooner he acquires that part of his training the better, because it will have to be thoroughly learnt sooner or later if he wishes to be successful. If he shows himself to be a good timekeeper and a reliable fellow he may be chosen one day to take part in a trip of, say, a torpedo-boat destroyer about to undergo speed trials. Some small duty will be assigned to him, which, though small, will nevertheless form a link in the chain of duty which binds the whole crew together during the trial. Failure on his part may compromise the trial. Here is an opportunity to show grit. Wet through to the skin, or perhaps half baked and choked with dust in the unfamiliar environment of a closed-in stoke hole, he must carry out the job assigned to him with punctilious care, and after a successful run he will devour a grimy meal in grimy surroundings with a feeling which a king might envy. His training in responsibility has begun. He feels himself a man, a man who has performed his part with other men; a man who has done all that was expected of him, and perhaps a little more. Training of this kind is invaluable at the outset, and fortunate indeed is the youth to whom such opportunities come early.

In this preliminary year's training there is an element which must not be neglected. The fascination of the daily work will tend to absorb all the youth's interest, but it must not be allowed to do so. He must think of the future and the college course which is before him, and must begin to prepare himself so that he will be able to take full advantage of the college instruction. To this end there are two subjects to which he should devote a definite time every week, and these are mathematics and mechanical drawing. Mathematics is a subject the elements of which he has probably learnt at school; these elements must not be forgotten, but must be used as a foundation on which to build. Mathematical skill is acquired slowly and only with constant practice, and if, either by natural aptitude or by the inspiration of his teachers, he feels the fascination of this wonderful product of human thought his progress will be assured. But anyhow he must study the subject. Rightly understood, it is one of the most powerful tools that an engineer can ever possess, and it will help him in his subsequent studies to an extent of which at the present stage of his training he will have not a glimmer of a conception. Let him take a book like Rankine's Applied Mechanics, and try and read the first few chapters. Unless he has already acquired a good deal more mathematics than most boys he will find it almost incomprehensible, as incomprehensible in fact as if it were written in a foreign language. He will be wise if he decides to close the book with the determination to master the language in which it is written. In a few years he will be able to follow the thoughts of the greatest writer of engineering science we have ever had, untroubled by difficulties of the mathematical language in which they are expressed.

Mechanical drawing is equally another language, the language in which the constructional engineer expresses his thoughts, in which he silently gives his orders to the va-

rious departments of the works; a language as exact as mathematics, and which is understood universally by engineers, but which is about as intelligible as the hieroglyphics on an Egyptian monument to those who have not learnt to read or to make a drawing. No matter what may be the apparent difficulties, instruction in these two subjects must be obtained. For the time every other subject may be let go. Intellectual development will make good progress if endeavor is concentrated on these two subjects alone.

Let us now suppose that the year's training in the works has come to an end. He is ready to enter on a college course. We may presume that he has learnt that the immediate work assigned to him must be carried out with all his energy and with a concentration of thought upon it regardless of inclination; that he has realized the meaning of the word responsibility; that he has increased his knowledge of mathematics to a point where he can begin to use it as a tool in the simpler problems, and that he has acquired a skill with drawing instruments which will enable him to make a neat tracing and to make a working drawing of simple constructional details properly dimensioned and finished off. The question arises: what is the best college at which he can continue his training? The answer to this question is that there is no best college for his purpose.

The college course now contemplated involves instruction in scientific principles common to all branches of engineering, always keeping in view that these principles should be illustrated by applications to the problems of marine engineering as far as possible. The subjects of study during the first year at college should in the main be of an unspecialized character. About one-third of the time should be devoted to mathematics, one-fifth to mechanical drawing and machine design, and the remainder to chemistry and physics. In this way the subsequent specialized work will have a good scientific foundation. The instruction in the second and third years should be given up mainly to subjects which have a direct bearing on the profession of a marine engineer; drawing and mathematics should still be continued as an integral part of the work. The special subjects may be enumerated roughly as follows: Strength of materials, theory of structures, kinematics of machines, heat engines, thermodynamics, hydraulics, including hydraulic machinery and the resistance and propulsion of ships; dynamics, electrical technology.

The importance of the first subject to the constructional engineer requires no emphasis. The course of study should be mainly experimental. All the ordinary materials of construction should be actually tested by the student in a testing machine, in order that he may gain by actual usage a thorough knowledge of their strength properties. The lectures in connection with this work would cover the subjects of stress and strain in general. Without considering the scope of each subject in detail, the general principle operating in the teaching of them all should be that fundamentally the object is, not to teach the scientific principles connected with the subject, but to teach these principles through their application to cases which fall within the general practice of engineering. To give an example: the theory of the motion of a rigid body about a principal axis may be taught mathematically and illustrated, say, by examples taken from the motion of the planets, in which case the student gains no feeling of the practical importance of the principles, and does not learn to associate the work with any of the peculiar problems belonging to the marine engineer; he rather regards the whole matter as something good in itself, very interesting no doubt to purely mathematical people, but as having as much in-

fluence on the business of a marine engineer as the planet Neptune has on the motion of the earth. On the other hand, the theory may be associated at the outset with problems connected with the balancing of a marine engine and during the development of the principles concerned the interest of the student would be caught and in the end he would have learned the same scientific truth, but in a way which would enable him to apply it to practical cases. The technical language of the engineer has been used throughout in the teaching of the principle, and the student has felt that he was engaged in learning an important part of his profession.

Again, to take an example from the kinematics and dynamics of machines, a student who thoroughly studies the motion of, let us say, the slide valve, operated by almost any form of valve gear, and tries to ascertain the stresses in the links of the gear due to fast running, will require to use most of the principles of kinematics and dynamics regarding plane motion, and having learnt them in this way he will be able to apply them to other problems as they arise in subsequent practice.

During the whole of the teaching of the subjects enumerated above, the main object should be carefully kept in view—the inculcation of scientific principle through its applications to engineering practice, and not a catalogue-like enumeration of formulæ regardless of the scientific principles on which they have been based. Two years' instruction of this character would be sufficient in most cases, and might appropriately be followed by more work in the shops and by some experience at sea. An ambitious youth, however, confident of his powers and anxious to obtain knowledge of current developments, could with advantage supplement this training by taking a course of specialized instruction of an advanced character. In many cases this advanced course might be taken as a fourth year at college if such an advanced course were available. The continuous four years' college course has advantages as against a three years' course followed by a year or two in practice before the fourth year is taken. The decision of a youth in this matter would be influenced by different circumstances in each case, and particularly by the fact that the organization of specialized engineering instruction of an advanced character has made but little progress in this country.

There are many institutions where adequate training in the scientific principles underlying engineering practice may be obtained; for instance, the universities of Cambridge, Glasgow, Edinburgh, Aberdeen, Liverpool, Victoria, Leeds, Sheffield, Durham, London, and, quite recently, the ancient University of Oxford, all compete in this matter. But at present it cannot be said that specialized instruction of an advanced character in marine engineering has received the attention and support commensurate with the national importance of the industry to Great Britain. In fact, definite courses in marine engineering of university standard are given at Glasgow and Durham universities, only at the former place under the heading of naval architecture, including marine engineering. In the future specialized instruction of an advanced character in marine engineering and naval architecture may be organized in connection with the Imperial College of Science and Technology.

In America the Massachusetts Institute of Technology early in 1891 included naval architecture as an optional subject in the course of mechanical engineering, and two years later a regular course was established, and lectures are now regularly given in ship construction, naval architecture, ship design, marine engineering and theory of war-ship design. In addition to this, a special course suitable for naval construction has been arranged for the purpose of giving advanced instruction

to graduates of the Naval Academy.

In Germany courses for marine engineers are provided at the technical universities of Charlottenberg and Danzig, besides many courses of a less advanced character at the *Technikums* of the country, as, for instance, Bremen, Hamburg, Altona, Kiel, Stettin. The following statement of the technical subjects of study at Charlottenberg will indicate what is thought to be necessary in Germany for the training of a marine engineer:

First Year.—Experimental physics, higher mathematics, mechanics, descriptive geometry, marine construction, mechanical technology and manufacture of iron and steel, chemistry, drawing, strength of materials, laboratory, introduction to electrical technology.

Second Year.—Mechanics, machine construction, lifting machinery, drawing (connected with the lines of a ship), boilers, graphic statics, mechanical technology, thermodynamics, engine laboratory, electrical laboratory.

Third Year.—Ship engines and turbines, heat engines, construction of war ships, theory of ship design, boilers, ships' machinery, engineering laboratory, electrical laboratory.

Fourth Year.—Design of ship machinery, design of electrical machinery, applied dynamics, hydraulics, refrigerating machines, testing of materials in the royal laboratories at Gross-Lichterfelde.

A student makes a selection from these subjects, acting under the advice of the professors.

When college course and shop training, including some experience at sea, have been obtained, what then? There are other qualities necessary to a marine engineer besides those susceptible of being trained by the methods enumerated above—qualities which elude both practical and academic training—qualities which enable a man to direct other men, which enable him to read the signs of the times and to be able to take advantage of them. Resourcefulness, reliability, tact, all are wanted in the character of a successful engineer. The purpose of this article is fulfilled in discussing the common training which every youth might undergo with advantage who desires to become a marine engineer. The development of the more subtle qualities of his character elude rule and method and depend largely on the stimulus applied by the example of others and on the environment in which he passes his days.

THE REPAIR AND MAINTENANCE OF SHIPS

By C. H. Hall and S. H. Bunnell

THE ocean-going ships of one hundred years ago were constructed of wood, ropes and canvas, held together with wooden tree nails and the smallest possible amount of forged iron bolts, nails and straps. In those days there were no docking facilities by which a vessel might be removed from the water for convenient access to the exterior, nor were there any diving equipments by which men could work below the water-line of the ship as she lay at her moorings. The only possible way that access could be had to the exterior of the hull was by listing the vessel by shifting the cargo or guns; or, in port, by the use of heavy masthead tackle the hull could be exposed beyond the keel. This operation, called "heaving down," was not infrequently performed during the progress of a long voyage by the early circumnavigators of the globe, the vessel seeking a quiet port for the purpose of having her hull cleaned and inspected.

The ship's crew was expected in those days to maintain the condition of the ship, most repairs being made during the progress of the voyage. The direction of the ship's repairs lay with three men, the ship's carpenter, the sailmaker and the boatswain. The ship's carpenter was supplied with a well-filled chest of tools, and was expected to make with his own hands, or the assistance of seamen unskilled as carpenters, any repairs to the woodwork of the vessel or equipment, from patching a broken spar to building a boat from forest trees to carry away the survivors of a shipwreck. The sailmaker was constantly engaged in repairing or making sails. During the stormy Cape Horn passage it was not unusual to lose two or three suits of sails, yet the effort was generally made to have the ship arrive in port with fairly new canvas and all the paintwork glistening. The boatswain had charge of all ground tackle and rigging, and repairs and replacements were a matter of daily occurrence, being made under his direction by the crew, who were experienced in "marlin-spike" seamanship, so termed from the tool used to open the strands of a rope for splicing.

On a ship-of-war the carpenter had assistants termed carpenter's mates. The rating of "carpenter" still exists in the navy, although at present he is required to be an expert in steel construction. The repairs in the old days were made by hand-tools and manual labour only, but the speed and thoroughness of the work could hardly be surpassed even at the present day. Records of naval engagements frequently contain such paragraphs as follows:

"By dark of the day of action the prize was in condition to make sail, and our foreyard had been fished and sent aloft."

With the passing of the wooden ship and the advent of the steel-constructed, engine-driven ocean liner with its elaborate saloons, staterooms, decks and luxurious passenger accommodations, together with the limited stay in port necessitated by the rapid schedule of present days, the question of repairs becomes one to tax the utmost efforts of every trade of civilized life. The heaviest work falls to ironworkers and boilermakers, machinists and engineers; next come carpenters, caulkers, joiners, elec-

tricians, coppersmiths, sheet-metal workers, plumbers, riggers, blacksmiths and painters; but the list might be indefinitely extended to cover upholsterers, cabinet makers and other workers skilled in repairs to instruments, utensils and fittings of navigator's, stewards' and cooks' departments. The best accommodation offered the passenger traveling by the wooden packet was simplicity itself, crude and comfortless. The steamship of to-day, however, coming to port after a voyage, requires the services of men skilled in ten or twenty different trades, and with a limited period of three or five days at most in which to make whatever repairs or alterations are found necessary.

The magnificent equipment of the repair departments of large industrial works and railroads has lifted the business of making repairs into one of the important branches of mechanical work. In none of these shops, however, is so diversified a class of work undertaken as is required in making repairs to sea-going ships. In case of accident, such as the breakdown of an engine of one of the large trans-Atlantic steamers, extraordinary pressure is exerted to obtain the utmost speed in making repairs, to the end that the ship may not be detained beyond her schedule. A vessel of only moderate size may represent a capital of half a million dollars, while the fast mail steamers subsidized by national governments represent a value of several millions, so that every idle day during a busy season means the loss of an enormous earning capacity. If one hundred locomotives were to be withdrawn from service for repairs, all to be held for the same period and returned for work at the same moment, the railroad repair shop would be

REPAIR WORK IN PROGRESS AT THE YARDS OF THE GRISCOM-SPENCER COMPANY, NEW YORK

subjected to a requirement similar to that governing the repairing of a large steamship.

The work on vessels in port is not undertaken merely to make good damage or wear. It is said, "A ship is never finished until she is sunk." New conditions arise from time to time. New vessels are put into service with superior accommodations and fittings and elaborate equipment, and at once it becomes necessary to refit older ships to offer similar advantages or suffer a large loss in earning power. A vessel may be offered a shipment of live cattle and must put in proper stall fittings; but on the next voyage she perhaps carries a bulk cargo, and the fittings are removed. The next shipment may be of heavy pieces, such as cut stone, requiring heavy shoring; and next a circus, the wild animals requiring special ventilation and care, and so on during the life of the ship. No matter what the nature of the work, speed must be obtained at any cost. The vessel must not be detained beyond her sailing date, though men work three or four days without sleep or rest. Expensive forgings or bronze castings often replace cast iron or steel, there being no time to wait for the slower processes. The coaling of the vessel may take place while repairs are still going on, the coal being rushed into the bunkers as ironworkers drive the last rivets and painters go over the work previously done to cover up damage by passing workmen.

RECONSTRUCTION OF THE JOHN A. WARNER

It is evident that the repair force must be thoroughly organized under a competent chief with authority over all hands, and at the same time with skilled foremen to look after the

work of each trade. It requires the most careful planning to work several forces of men in close proximity to each other without too much interference. Only long experience with good foresight enables the superintendent to plan the exact state of the work at each hour, so that the last workman may have his task completed before the hour of sailing arrives. The organization of the repair yard is, therefore, military rather than functional (to use the terms of the most prominent organizers of industrial work), and is thus opposed to the most modern practice of manufacturing organizations. The superintendent is the head of the force of workers, his orders being given directly to the foremen, each of whom has charge of the work done by his men.

The records of any repair yard would be full of interesting stories but for the fact that in the rush of the work the taking of pictures and the making of proper records is usually overlooked. Much of the most difficult work is done in situations where photography is impossible. The variety of work which comes to a repair yard is surprising to one who is unfamiliar with the business. For instance, the records of one corporation, the Griscom-Spencer Company, of New York, include the construction of a floating electric-welding equipment for hull repairs; the renewing of the tank tops of the steamer *Admiral Sampson,* the engines being suspended meanwhile from the main deck; installing evaporating apparatus on large ships in four days; making and fitting cast-iron rams, 12¾ inches in diameter by 14 feet long, for hydraulic cargo hoists, the plungers being cast in loam; extensive repairs to the mine-planting steamer *Major Samuel Ringgold,* including wireless telegraph appliances and minor details down to matching electric-light shades and berth curtains; and the construction of an ornamental glass-enclosed staircase on one of the fast trans-Atlantic steamships in four days, including Christmas and a Sunday.

The extent and character of the repairs made by the Harlan & Hollingsworth Corporation to the iron sidewheel steamer *John A. Warner,* now the *Burlington,* are shown by the illustration from a photograph taken during the progress of the work. As one of the shipyard employees expressed it, "We overhauled the engine and boiler and built a new boat around them." The *Warner* was placed in the dry dock and 137 hull plates renewed, the engine and boiler being meanwhile shored up from the bottom of the dock. All the joiner and carpenter work down to and including the main deck beams was removed and renewed. The photograph shows the work when the process of removal was about completed. The work of reconstruction occupied about two mnoths. This vessel was the second oldest boat on the Delaware River, being originally built in 1857, and the peculiar feature of her construction was the extreme lightness of the scantling. Her frame consisted of flat bars on edge, and the plates were secured to these by light staples of flat iron riveted to the shell.

The capacity of the New York yards for making hurried repairs is well shown by the case of the *Asbury Park.* This vessel, one of the Sandy Hook fleet of the Central Railroad of New Jersey, rammed the ferryboat *Red Bank,* of the same company, while approaching her pier about 10 o'clock one Thursday morning. Her bow was badly buckled and twisted to port. By the use of the telephone a dry dock was promptly engaged, while the vessel made one more trip to the Highlands and return according to her schedule. She was docked at Tietjen & Lang's about 3.30 P. M. of the same day, a survey made and work begun immediately. The entire stem was removed, straightened and replaced; the shell plating was removed from the deck

DAMAGED HULL OF THE STEAMSHIP FORTUNA

to the forefoot and renewed, and new guards, bulwarks and rail were fitted where required. There was no interruption to the work until its completion on the following Monday in time for the regular trip of the boat at 5.40 P. M.

An example of difficult patching is afforded by the repairs to the rudder of the American Line steamship *Philadelphia.* The vessel came into port with the rudder stock cracked nearly through, the crack extending almost entirely across the width of the blade. Repairs were undertaken by the James Reilly Repair & Supply Company, now the Griscom-Spencer Company. A plaster cast was taken of the surfaces of each side of the rudder, and from these casts manganese-bronze patch plates were moulded. These plates were applied to the rudder on opposite sides and secured by bolts, after which a number of holes were tapped through the patches into the rudder and short pieces of wrought-iron pipe screwed in, after which each ferrule was reamed and

HOLE STOVE IN THE SIDE OF THE STEAMSHIP LIGURIA

filled by a steel pin driven home by a heavy sledge, the threads on the ferrule taking the tensile stress, while the steel pin sustained the shear.

An important repair job was done by this yard on the steamship *Alaska,* of the Guion Line. Two new crank-shafts 24 inches in diameter, weighing 22½ tons each, were installed and fitted to bearings; one new piston and rod, cylinder and valve-cover and four new thrust shoes were supplied, the other thrust shoes rebabbitted, six pairs of main crosshead brasses made, guide shoes and crank brasses rebabbitted, all eccentric sheaves returned, straps rebabbitted, refrigerating machine refitted, and all other parts made good as necessary. The time of the work was thirty days, working continuously from start to finish.

The steamship *City of Montreal* had a steeple-compound engine, two high-pressure over two low-pressure cylinders. She came into New York harbour with the crosshead pin of the forward engine broken, and the James Reilly Company was called on for the repair. The pin was re-

moved, holes in fork-end bored with a portable bar, a new pin, 14 inches in diameter by 28 inches long, was forged, turned and shrunk in, and brasses fitted. The job was finished, by the hardest work, in seventy-two hours, and the vessel left on schedule time, only to be burned at sea after being out about four days.

Another difficult repair undertaken in the same yard was the patching of broken engine columns on the American Line steamship *New York*. These columns were cracked through just below the cylinder seatings. In this case also plaster casts were taken of the surfaces on each side of the breaks, and manganese-bronze castings in the form of angle pieces made by moulding from the plaster casts. These patches were applied and secured by drilling and tapping holes through the patches and columns and the use of steel ferrules and pins, as in the last case. These repairs were completed between Saturday and the Wednesday of the week following.

Successful repair of a break which looked hopeless was made by the same company on the MacInness steering gear of the Red Star steamship *Friesland*. The vessel arrived on Saturday with the quadrant broken through all three arms. This quadrant was a steel forging, and replacement within a reasonable time was impossible. Plaster casts were made and iron castings moulded to fit the triangular spaces between the arms. On this work the foundry was run day and night to save every possible moment. The castings were applied in the manner intended, all necessary holes having been cored; then ¾-inch steel plates were placed above and below the quadrant, with holes drilled to match the castings, and the plates were bolted securely together, clamping the three broken arms firmly to the cast-iron segments and the rim. The success of this repair is best made evident by the fact

INTERIOR OF THE DAMAGED LIGURIA

that the vessel, although provided with a new steel forging when next in port, made five complete round trips before the patched quadrant was removed and the new one substituted.

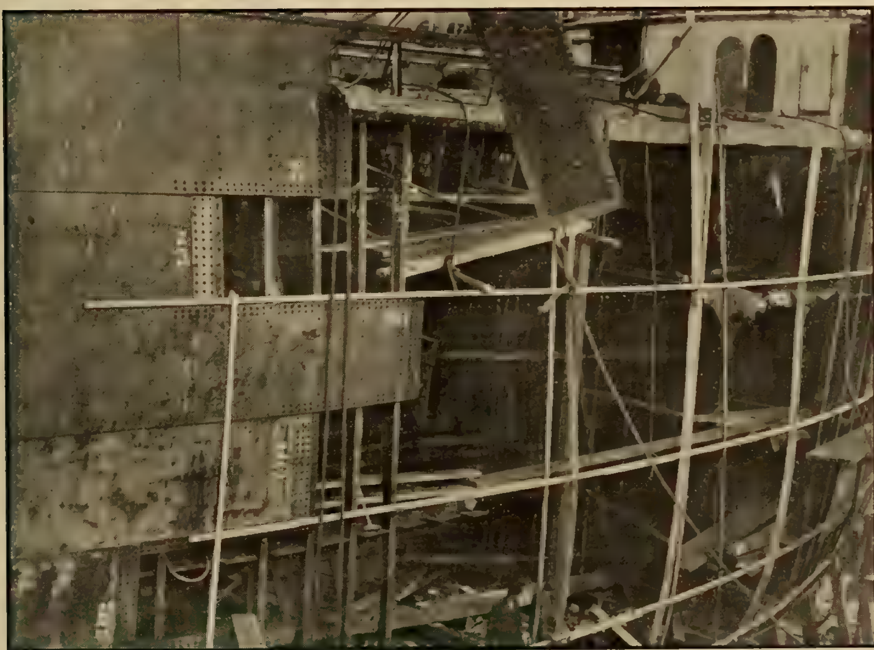
Shortly after the formation of the International Mercantile Marine Company the sailing schedules of the American and Red Star Lines were changed so as to allow but four days in port, the round trip of the fastest ships being made in three weeks. Repairs to the vessels of these lines were regularly made by the James Reilly Repair & Supply Company, and the organization was especially adapted for completing the work in the shortest possible time during the ship's stay in port. In order to get at the propeller and stern bearings a portable cofferdam was provided, with a rubber joint fitting around the shaft. When placed in position and pumped out, this allowed repairs to be made as required without the delay and expense of dry-dock-

THE TORDENSKJOLD ON THE BEACH NEAR QUEBEC

ing the ship. A force of men commenced work almost the instant a vessel touched her wharf, and the work proceeded night and day, while the engines were dismantled and refitted as required, crankshafts adjusted, bearings scraped or refilled, complete equipment of boilers scaled and cleaned, and all necessary repairs completed before the hour of sailing.

In one of these intervals the main crankshafts of the American Line steamship *Paris,* each weighing 15 tons, were taken out and replaced. This work required the forging of eighteen 4½-inch coupling bolts by the only available steam hammer in a single night. All holes were reamed and bolts fitted, the engines taken apart and adjusted, bearings refitted and the work completed between 7 P. M. Saturday and 5 A. M. of the following Wednesday.

The character of the damage suffered by the hull of a steel steamship by contact with rocks is well shown by the photograph of the hull of the *Fortuna.* This vessel grounded on a ledge of rocks and was badly damaged, as the illustration shows, the lower part of the stem being broken away, frames broken or bent and plating torn. She was repaired by James Shewan & Sons, New York. The broken plates were cut away by the use of compressed air tools, a new portion of the stem was forged and scarfed to the broken part, and the damaged frames cut away and replaced by new material wherever required. In several cases of extensive damage to the hull plates of large ships dynamite has been used to expedite the cutting away of heavy plating, with a great saving of time.



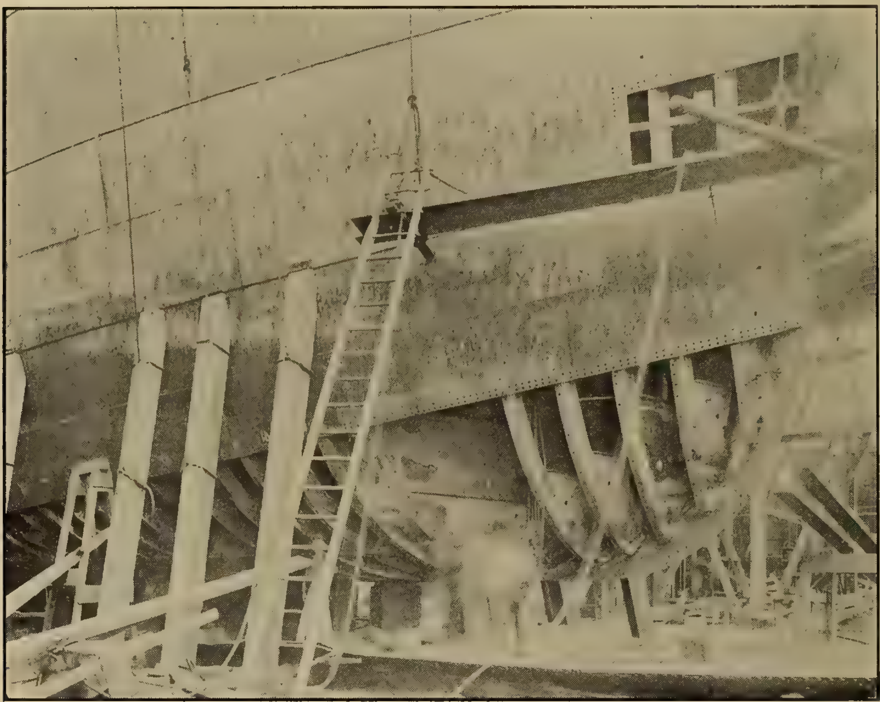
TORDENSKJOLD—DAMAGED PLATES BEING REPLACED

About eighteen months ago the steamship *Liguria* collided in the Narrows with the *Peconic.* The photographs were taken as the vessel lay at her wharf, and show clearly how frames, plating, stringers, beams, etc., were torn and buckled. The immigrants' quarters were located at the point of impact; but by good fortune

the collision took place in daylight, and so no lives were lost. The vessel was repaired by the John N. Robins Company, of New York, all damaged material being replaced by new, and the vessel delivered to the owners after seven days and nights of continuous work.

Another important repair was made by the same company on the Norwegian steamer *Tordenskjold.* This vessel was in collision with another steamship in the St. Lawrence River and a large hole torn in her hull. To prevent sinking she was beached near Quebec. The first photograph shows the vessel as she lay on the beach at low tide. The John N. Robins Company made temporary repairs and brought the vessel to Erie Basin, New York. The damage to plating and frames was extensive and required the removal of a large section of the ship's side. The second photograph shows the vessel in dry dock, and was taken when the damaged plating had been removed and the new work begun. The wooden strips or "ribbands" by which the new plates were laid out and the templates to guide in the restoration of the vessel's frames are conspicuous.

The photograph of the steamship *Mancunia,* injured in stem, forefoot and bottom by grounding, was taken in dry dock after the damaged plates, frames, etc., had been cut out or faired and when the work of reconstruction was well advanced. Repairs to this vessel also were made at Erie Basin by John N. Robins Company. Three frames have been removed at the figures 6, 7 and 8, to be replaced by new ones, and some of the new plates, curved ready for putting in place, are in sight on the floor of the dock.



THE STEAMSHIP MANCHURIA IN DRYDOCK

Besides the extensive repairs necessitated by special causes, since all steel vessels are docked at frequent

intervals for cleaning and painting, the numerous tugs, ferryboats, lighters, car floats and other vessels in any large harbour provide a considerable portion of the work of the repair yards. For instance, four small coal barges are frequently docked together or two tugs hauled out at the same time, while stern bearings are refilled, propellers renewed, bottoms searched for possible leaks and caulking touched up. In the case of ferryboats a regular schedule is often made out in advance, the vessels being docked at stated hours and the work on each, including cleaning and painting, renewal of leaky rivets, refilling of stern bearings, renewing of propellers and grinding sea valves, completed within thirty-six hours without being obliged to resort to overtime labour.

Marine practice in making repairs thus differs widely from the system existing ashore, since economy in doing the work is of no importance in comparison with the ouick resumption of service in transportation. Marine repairs must be successful; there is no opportunity to try one method and, if it fails in service, call on the shop to try something else. Under the operation of these two conditions shipyards engaged in the marine repair business develop an equipment of tools and a force of men capable of successfully undertaking any operation or construction known to the world of engineering or conceivable by the brain of man.

THE DESIGN OF FAST OCEAN STEAMERS

By E. W. DeRusett, M. Inst. C. E., M. Inst. N. A.

THE fast ocean steamer of to-day has been developed with amazing rapidity since the Peninsular Company—the pioneer of the "P. & O."—commenced operations in 1837 with the *William Fawcett,* followed by the Royal Mail Company, who opened their line in 1839, and the Cunard Company, a year later, with the *Britannia.* Had it been prophesied seventy years ago that luxurious floating hotels would have been steaming across the ocean at speeds approaching thirty miles an hour, the sanity of the prophet might reasonably have been questioned, yet it is an accomplished fact to-day. The little, creaking wooden hulls of those days, ranging from 100 to 200 feet long—the former smaller than an ordinary Thames or Tyne ferry steamer—propelled by low-pressure, slow-moving, throbbing engines, together with all the accompaniment of cramped space, ill-preserved food and other miseries of early ocean travel, have been gradually changed, stage by stage, until the present speedy floating palaces have been produced—monuments of skill, taste and refinement—to be increasingly appreciated by comparison with that which has been.

Ocean traveling is no longer a dreaded horror, but a delightful anticipation, where the ordinary mortal, whether of the weaker or sterner sex, will find every comfort provided with careful forethought and lavish profusion, while the dreaded old enemy, *mal-de-mer,* is conspicuous by his absence.

When contemplating the latest present-day wonderful productions of the shipbuilders' and engineers' skill, should we ask if the last word has been said with regard to fast ocean steamers the response would doubtless be in the negative. We could hardly expect any other reply, considering there is scarcely any finality as to possibilities both in design and construction. But at the same time there are doubtless practical limits to dimensions and speed, as the power, and consequently speed, is directly influenced by the facilities afforded by the ports of call, the depth of water available, and the coal-carrying power of the vessel for steaming long distances, besides the cost and the prospects of a reasonable return for money invested, which, after all, is the final limiting and determining factor. Touching on this, it will be interesting to note some of the difficulties which had to be surmounted in the instance of the latest and fleetest greyhounds of the Atlantic—the *Mauretania* and *Lusitania*—where the question of waterway and docks was a most serious one, as the draught was not to exceed a stated limit, the length and breadth such as would go into existing docks, and on these three elements of draught, length and breadth the speed depended, as the power which controlled the speed was limited by the space which could be devoted to the propelling machinery, and the more vital factor of weight of machinery

could not exceed a definite proportion of the load displacement if anything was to be left for the carriage of passengers, baggage and freight after the fiery appetite of the furnaces had been provided for.

The problem, therefore, resolved itself into this: How much power, with sufficient coal to steam across the Atlantic, could be placed in a vessel of given extreme dimensions and draught and the vessel modeled to suitable fineness for the desired speed?

As these vessels so far exceeded the dimensions and speed of the longest and fastest liner then existent, the solution of the problem became a matter for exhaustive calculation and careful experiment, and much time was absorbed in these preliminaries.

The problem of fast ocean navigation is beset with difficulties, that of the weather being one of the chief, as there is scarcely any factor which gives greater concern to constructors and navigators. This may be illustrated by reference to the performances of these two latest additions to the Cunard fleet. Without particularizing, it may be stated that an average sea speed of 24¾ knots (28½ miles per hour) has been obtained during an all-round voyage to New York and back, also a mean speed of 25.2 knots (29 miles per hour) during three consecutive days, and on one day's run in August, 25.66 knots (29½ miles per hour) was steamed; besides, an average speed of 26.4 knots (nearly 30½ miles per hour) was made during the trial trip

P. & O. CO.'S PIONEER STEAMER WILLIAM FAWCETT, 209 TONS REGISTER

of one of these famous liners over a distance of 1,200 nautical miles, and 27.36 knots (31½ miles per hour) over a course of 300 nautical miles. With these figures before us it may be a surprise to learn that during a very stormy day in January last when crossing the Atlantic it was found necessary to reduce the speed to 16.8 knots to avoid risking serious damage to the superstructure, yet on the day following she averaged 23.2 knots, and again on another occasion the average speed was reduced to 19.5 knots, owing to a continuance

THE MAURETANIA, SHOWING THE ROUNDED ENDS AND STEPPING BACK OF DECK HOUSES. THE SMALL BOAT IS THE TURBINIA, THE FIRST TURBINE-PROPELLED BOAT

A SNUG CORNER IN THE UPPER DINING SALOON OF THE LUSITANIA

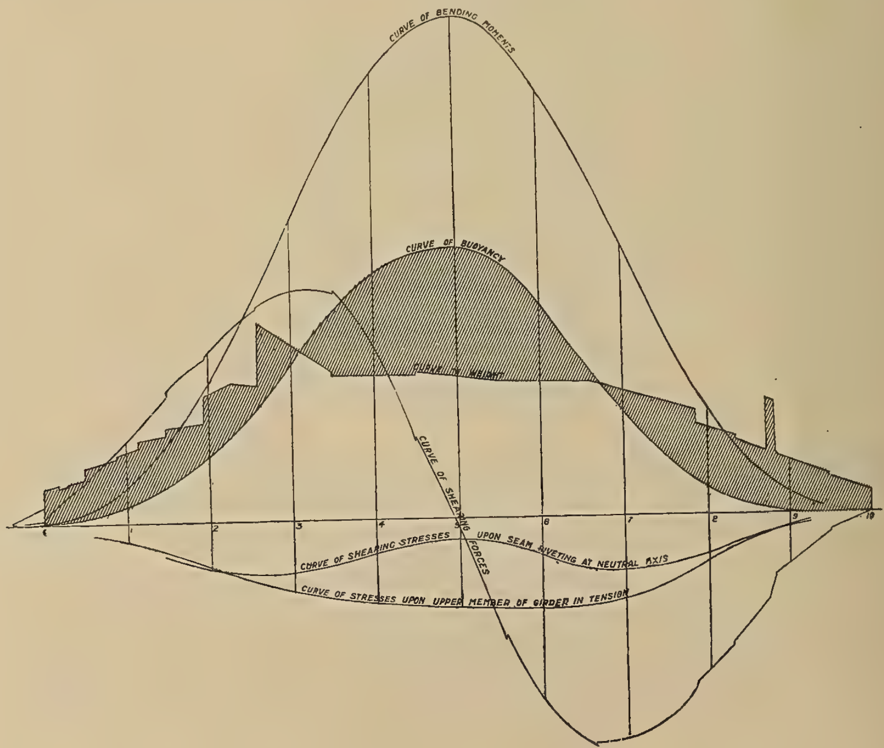
of very bad weather. In fact, on more than one occasion seas have come aboard and have ruthlessly disturbed deck fittings and battered against the fronts of deckhouses and bridge bulwarks, though they are from 55 to 80 feet above the normal water-line; and on one occasion an 8-ton spare anchor—stowed on the weather deck more than 40 feet above the water-line and sheltered under the lee of a strong bulwark—was loosened from the strong clamps which bound it to the deck. Yet in such seas the machinery itself gave no anxiety, for the turbine engines were unaffected by the pitching and rolling of the ship, neither did they race in a seaway; and, in fact, from this point of view, they are practically perfect. It will, therefore, at once be realized, where turbines have taken the place of reciprocating engines, that the determining factor of the speed limit under all conditions of weather rests with the shipbuilder.

Before proceeding further it may be of interest to remind the reader of some of the lesser difficulties which the naval architect has to contend with. To those who have made an ocean voyage it will be readily granted that the foundation which bears up the structure is a very unstable one; but to those who have not yet had this experience a description of the motion which a vessel sometimes experiences at sea may be of interest and an assistance in grasping the reason for the peculiar provisions which have to be made in the design and construction of a ship, besides giving some idea of the strains which come upon the structure and the fittings generally when in a heavy seaway. For instance, when a very large vessel is running before the sea in an oblique direction and rolling, say, 10 degrees from the vertical on either side, each side moves through a vertical distance of about 16 feet during a period of from 10 to 12 seconds, at the same time pitching and ascending probably to a height

of about 25 feet at the stem in 3 to 4 seconds. Then the whole structure, while rolling and pitching, may be heaved up bodily by some huge passing wave, the combined effect of which, should the whole process be repeated again and again, may be imagined rather than described, especially when Father Neptune is in a particularly sportive mood.

Imagine for a moment any shore structure, however strong, being subjected to such treatment! Even in the occasionally earthquake-stricken city of San Francisco the buildings were never so badly treated. Besides, the vessel itself being built of a material capable of stretching one-fifth of its length before absolute fracture takes place, will, when tempest-tossed, naturally adapt itself to circumstances, while the woodwork and fittings, which are not of this yielding nature, will quiver and creak unless provision has been made to enable them to accommodate themselves to the elastic material which encloses them.

For vessels of unusual dimensions and speed it is necessary to resort to calculations to arrive at the requisite scantling of the steel to endure the strain to which the vessel may be subject; but for those of ordinary design and size—vessels about 550 feet long by 64 feet beam—the designer has simply to refer to the rules of the Registry Society, with which the vessel has to be classed, when he will readily find the scantlings which have been proved by practice to be ample. We will presume for the present that the ship comes under the former category and that stress calculations must be resorted to. The first thing is to determine the maximum stress per square inch which it is possible the vessel will be subject to



STRESS DIAGRAM

when she is poised on a wave of her own length, having a height from hollow to crest of one-half of the length, the vessel being laden, but with bunkers nearly empty—usually the most exacting condition.

We will assume that the hogging stress has been fixed not to exceed 10 ton per square inch on the mild-steel basis—that is, of plate steel which will have a tensile breaking strength between the limits of 28 to 32 tons per square inch, the elongation of which shall not be less than 20 per cent. for a gauge length of 8 inches for material of 0.375 inch in thickness and upwards.

How the material is to be disposed is graphically illustrated by the accompanying bending-moment curve of the *Mauretania*.

Referring to the diagram for clearness, the portion of weight which is water-borne is indicated by shaded lines, and the excess of buoyancy amidships which is equal to the deficiency at the ends is also shown shaded.

The bending moment is due to the excess of end weight not being directly supported by the water, the excess of weight at these parts being carried by the excess of buoyancy amidships. The bending moment has its maximum value amidships, and the scantlings are such that the stress does not exceed 10 tons per square inch at this part on the mild-steel basis.

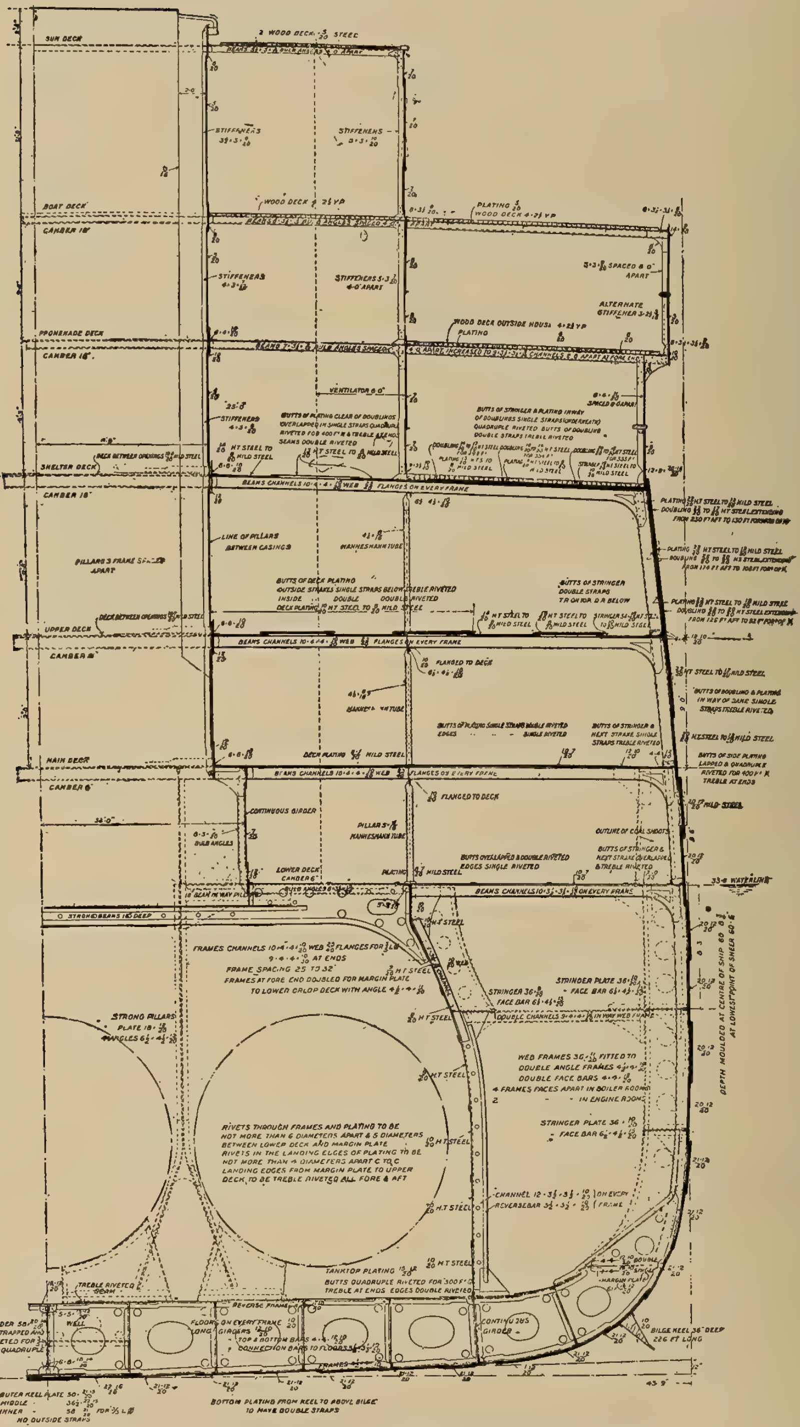
The curve of stresses shows that the steel has been so disposed that the strength of the structure varies but little for a considerable length amidships, viz., between sections 3½ and 7.

With regard to the end scantlings, it may be pointed out that other considerations did not permit of the reduction being made which the shape of the curve of bending moments would seem to warrant.

To illustrate the distribution of material amidships and the reduction towards the ends, we refer to page 96, which is a drawing from the "Shipbuilder" of the midship section of the *Mauretania*. This section was designed for a maximum stress on the top member of 10 tons per square inch under the conditions already stated and assuming the material had all been of mild steel. However, to reduce the weight and secure the strength with plates of a more workable thickness, the three upper shell strakes and shelter and upper decks were composed of high-tensile silicon steel having an average ultimate tensile strength of 36.3 tons per square inch, with an elastic limit of 21.6 tons per square inch and elongation of 22.7 per cent. in a length of 8 inches. As a result, the stress was increased to 10.7 tons per square inch, a figure which provides a higher factor of safety than if mild steel had been exclusively used.

The shearing force at any section is the difference between the load and supporting forces on one side of that section and has its greatest value at about one-quarter length from each end, viz., at sections 2¾ and 7, at which parts special attention should be given to the seam-riveting of the shell plating either by close pitch of rivet or treble riveting. In the *Mauretania* the maximum shearing stress at these parts by calculation was 6.3 tons per square inch of cross-section of rivets, the seams being treble-riveted. In vessels of ordinary speed the calculated stress has reached 7½ to 8 tons per square inch without any recorded trouble having been experienced.

When designing the deckhouses the accommodation should be arranged that the houses may be so sub-divided in their length that they may not be subject to the stresses which come on the main structure; their scantlings have also to be carefully considered to stand the shock of broken seas and the twisting strains to which they are subject when steaming fast among waves. To combat the weather and diminish the wind resistance it is advisable to round and step back the ends of each tier of houses, and although they



MIDSHIP SECTION OF MAURETANIA, SHOWING DISTRIBUTION OF MATERIAL

must necessarily be of light construction, their scantlings should be strong and as homogeneous as possible and well riveted. The steel at the top of all doorways will require to be doubled, and square corners should be avoided at all openings for windows and doors, as at these parts stresses accumulate and the metal is liable to crack. Besides, the plating and riveting around any part of the house which may incidentally have to be of more than normal strength should receive special attention, as it is at such parts unusual stresses occur. The decks also should be specially strengthened locally in a fore-and-aft direction at the termination of deckhouses.

As reduction of weight has to be studied in fast ocean steamers, the use of India rubber and corticine will, where suitable, be found excellent substitutes for wood sheathing, being lighter, thinner, elastic and noiseless, besides affording good foothold. The steel decks will, therefore, be flush-plated and doublings placed on the under side where practicable.

The naval architect having before him the task of designing, say, a fast North-Atlantic liner, and knowing broadly the requirements of the owners, such as speed, draught and general arrangement, otherwise having a free hand, has in the first place to decide on a length most suitable for the purpose as a whole.

This, having regard to efficiency and economy, should not by common consent be less in feet than the square of the speed in knots, although, especially for North-Atlantic work, it has been proved by experience advisable to increase it by about 20 per cent. to reduce resistance and cope with heavy seas.

As a guide to determining the length, diagram page 98 will be found useful, as it shows at a glance the speeds at which vessels of similar models to those experimented on may be propelled with approximately abnormally great and small resistance. The curves are based on Mr. F. P. Purvis's deductions from Mr. R. E. Froude's experiments with towed models, to which we have added a curve of squares of speed and have plotted down the lengths and speeds of a number of fast Atlantic liners, by which it will be seen that they closely lie about a curve having a value of about 0.9 for the speed-length ratio $\frac{V}{\sqrt{L}}$, in which $V =$ speed, $L =$ length.

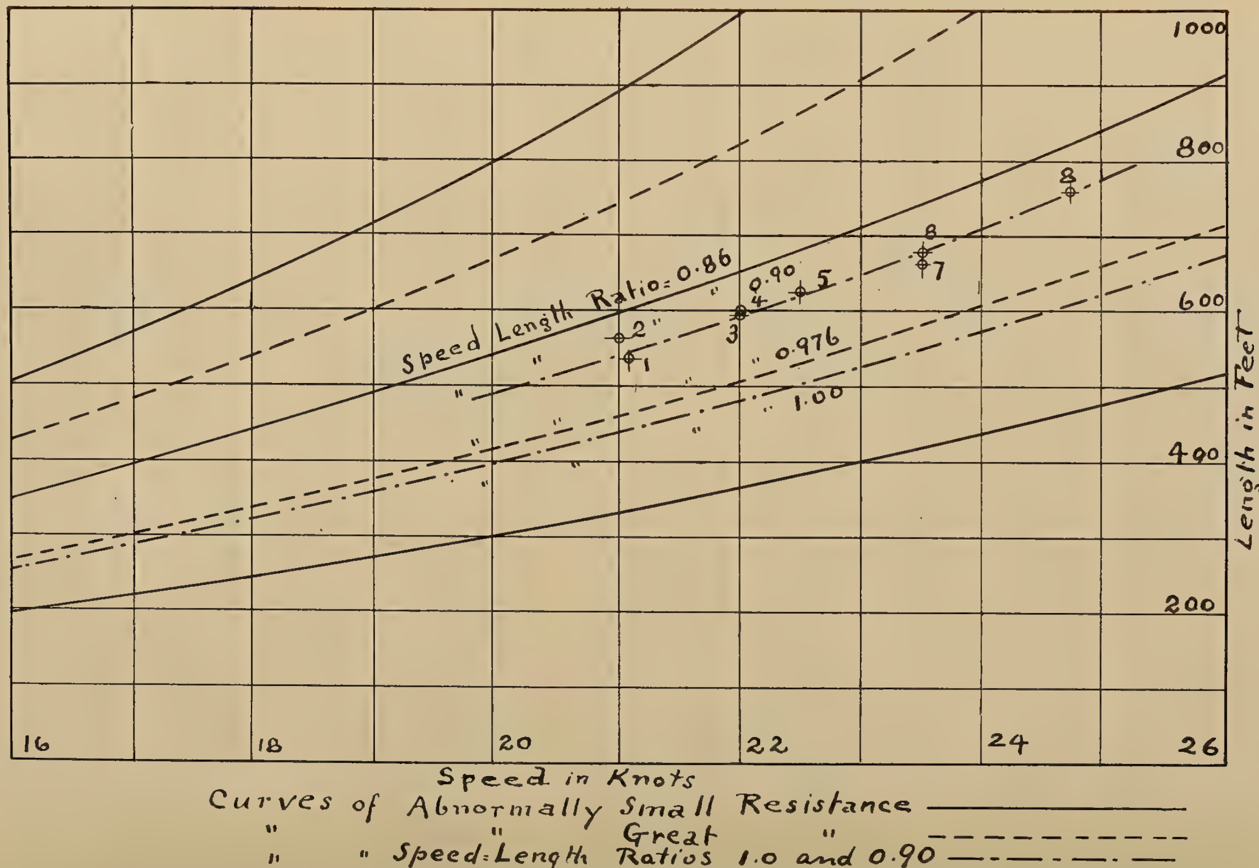
The diagram also shows that, by adding 35 per cent. to the basis length of V^2, the length will correspond to the curve of abnormally small resistance, which has a value for the speed-length ratio of 0.86.

The diagram also approximately determines the normal speed at which a vessel of given length should or should not be steamed. This can be arrived at by drawing a line parallel to the base at a distance corresponding to the length of the vessel and reading off the speeds where it crosses the curved lines.

As an example, if we trace the 600-foot line, we find that it cuts the great resistance curves at 23.9 and 19 knots and the small resistance curves at 21.1 and 17.4 knots.

To begin with, we will assume the required speed at sea is 23 knots at a sailing draught of 30 feet and a loaded trial speed of 23½ knots continuous steaming for twenty-four hours on 29 feet 6 inches mean draught. We will take out the length on the sea-speed with a speed ratio of 0.9. This gives a length of 650 feet. Thus $L = 1.23 \times V^2 = 1.23 \times 529 = 650$.

The speed, length, draught and type of engines (turbines) having been determined, the approximate fineness of model will next be considered. This is represented by the block coefficient or proportion of actual displacement to the displacement of a box whose length and breadth are those of the ships, the depth being the draught of water. It



SPEEDS AND DIMENSIONS OF PASSENGER STEAMERS

1, St. Louis, 536 feet long, 21.08 knots; 2, Teutonic, 565 feet, 21 knots; 3, Provence, 597 feet, 22 knots; 4, Campania, 600 feet, 22.01 knots; 5, K. W. d. Grosse, 625 feet, 22.5 knots; 6, Deutschland, 663 feet, 23.5 knots; 7, K. W. II., 625 feet, 23.5 knots; 8, Mauretania and Lusitania, 760 feet, 24.75 knots.

is governed by the length and speed. It needs correction where the relation of length to beam and draught to beam is abnormal, which is not the case in the present instance.

The block coefficient is first approximated by reference to known curves and formula and adjusted should the corresponding displacement of draught be found to be insufficient to carry the weights after checking. In this instance we will select a coefficient of 0.60.

Before the second dimension of the vessel, that of breadth, can be satisfactorily determined, it will be necessary to decide on a suitable initial stability for the laden vessel, or, in other words, the height of the metacentre above the centre of gravity (G. M.). This claims careful consideration, as the question of stability—especially in a passenger steamer—is of so much importance, as in it is involved the comfort of all concerned, and in a measure the speed of the vessel.

We will consult our records of the behaviour at sea of vessels of similar type to that contemplated. In the Cunard Company's intermediate steamer *Ivernia*—a remarkably easy ship—G. M. is about 1 foot 8 inches when laden. In the *Mauretania* it averages 2 feet 10 inches to 3 feet, and in easy vessels of 450 feet long with normal proportions and "top hamper" G. M. will be from 10 inches to 12 inches. These figures indicate an easy roll. We will decide on 2 feet to 2 feet 3 inches and then assume a breadth and moulded depth, afterwards adjusting the dimensions, if needs be, as the investigation proceeds.

On referring to our data and from experience we will try 73 feet 6 inches beam and 51 feet moulded depth, the latter ensuring a draught of 30 feet being assigned, besides providing an ample depth of girder for strength. The position of the center of buoyancy (B) above the base line will vary from 0.54 to 0.56 of the draught of water. We will assume this will be 0.55. Then the metacentric height (M) above the centre of buoyancy will be approximately determined by the formula: $\frac{B^2}{D} \times 0.07$ to 0.08. $B =$ breadth, D draught. We will asume the coefficient 0.072.

The height of the centre of gravity (G) above the base will vary from 0.52 to 0.54 in a vessel of the character we have in view. We will select 0.530, as the turbine engines will have a low centre of gravity. Proceeding thus:

	Feet
Centre of buoyancy $= 30 \times .55$	16.5
Metacentre above centre of B, $\frac{73.5^2}{30} \times .072$	12.9
Metacentre above base	29.4
Centre of gravity, $51.0 \times .530$	27.1
M above G ($G.M.$)	2.3

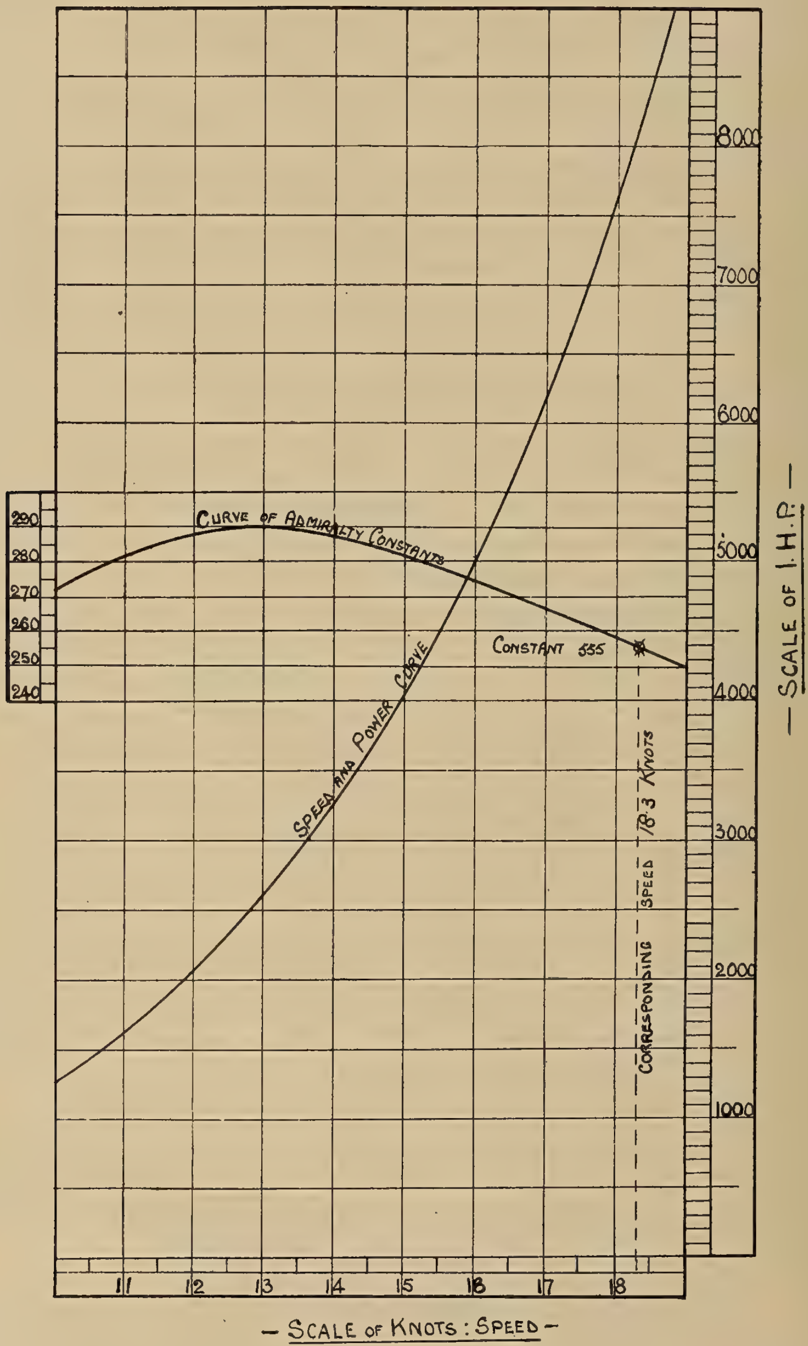
No alteration will, therefore, be necessary in the approximate dimensions, as this height is such a very close approximation to that aimed at.

The displacement will now be ascertained by formula: $\frac{L \times B \times D}{35} \times 0.60 = 24{,}550$ tons. Where $L =$ length, $B =$ beam, $D =$ draught of water, 35 being the number of cubic feet of salt water per ton weight and 0.60 the block coefficient.

The weight of hull and machinery, etc., will now be calculated to ascertain if the displacement is sufficient to carry the weights, and for this purpose we will estimate the power and hence arrive at weight of machinery and coal for the voyage.

The hull weight is usually approximated by a cubic number obtained by multiplying the length, breadth and depth and dividing by 100. In this case $\frac{650 \times 73.5 \times 51}{100} = 24{,}360$. For convenience the hull weight is usually divided into "net steel" and "wood and outfit," as detailed in the schedule.

There are various formulas in use for calculating the power, but



SPEED AND POWER CURVES

The Figures on the Left are Constants in the Admiralty Formula: $\text{H. P.} = \frac{D^{2/3}\,V^3}{C}$

the Admiralty formula, I. H. P. $= \frac{D^{2/3} \times V^3}{C}$, is as good as any for approximation. We will use the trial-trip speed curve of a vessel of similar proportions and block coefficient. The diagram is shown on page 100. It is of a vessel 400 feet long by 47 feet beam and block coefficient 0.615, with similar deck erections:

1st. To find the speed of the 400-foot steamer (A), which corresponds to the trial speed of 23.5 knots of the contemplated steamer (B). This will vary generally as square root of length.

Thus: $\sqrt{650} : \sqrt{400} :: 23.5 : x$, so that $x = 18.3$.

2d. The Admiralty constant by the curve = 255 at 18.3 knots.

On obtaining the Admiralty constant (255) for the large vessel from the trial results of the smaller vessel (page 100), a correction will be made for the frictional resistance, which will be relatively less for the 650-foot vessel. This, by calculation, will amount to 10, thus raising the constant from 255 to 265.

The twenty-four hours' speed-trial will be made on a sailing draught of 30 feet, the average draught being 29 feet 6 inches and displacement 24,100 tons. The indicated horse-power by the Admiralty formula: $\frac{D^{2/3} \times V^3}{C} = 44{,}000$.

The sea-speed of 23 knots in fine weather will be obtained with 36,800 horse-power on the same constant, but on a mean sea draught of 28 feet 10 inches and 23,450 tons displacement, corresponding to a sailing draught of 30 feet with half the coal, stores and fresh water consumed.

The mean sea displacement having been approximated, we find that the indicated horse-power required will be 36,800 to 37,000 and the coal per day $= 630 \times 20 \times 650$ tons. To steam, say, 3,200 knots at 23 knots per hour takes 5.8 days. The gross coal for the voyage will, therefore, amount to $650 \times 5.8 = 3{,}770$ tons, to which we will add 530 tons for bad weather, making a total bunker capacity of 4,300 tons.

The estimated weights will be by coefficients on the cubic number $\frac{L \times B \times D}{100} = 24{,}360$, in which L = length, B = breadth and D = moulded depth.

TABLE—APPROXIMATE ESTIMATE OF WEIGHTS FOR A VESSEL 650 FEET × 73 FEET 6 INCHES × 51 FEET

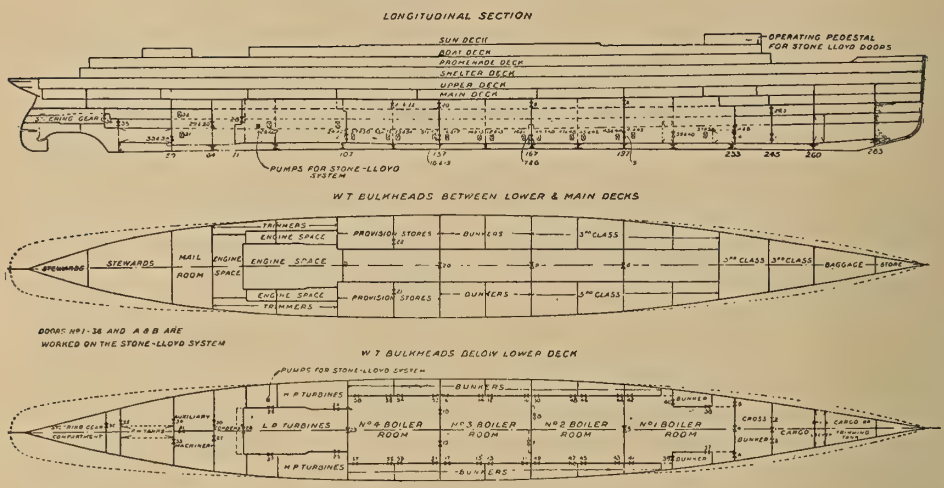
	Tons
Hull, net steel, at .375 tons	9,150
Wood and outfit, at .13	3,160
Engines, 44,000 horse-power, at .14 tons per indicated horse-power	6,160
Finished ship	18,470
Passengers and crew, say 2,500, at 15 per ton.	170
Baggage, stores, fresh water, and mails	570
Coal	4,300
Cargo and margin	1,040
Displacement, tons	24,550

Corresponding to a draught of 30 feet and block coefficient 0.60.

The dimensions, displacement, power and initial stability having been approximately determined, the curve of sectional areas selected and adjusted, the lines will be proceeded with and the hydrostatic curves got out. Special care will have been taken that the form of the after body and shaft bossings will be such as to ensure, as far as possible, a free horizontal flow of water to the propellers or half a knot may be lost. The deadwood will be cut away for manœuvring purposes and to facilitate flow of water to propeller and rudder.

The floor will be kept as long as possible and the vertical sections at ends be of the U form, to give buoyancy without resorting to full upper water-lines. The form above water will be as carefully considered as the lower portion, not only for appearance, but for resistance, the vessel having to encounter solid masses of water which rise high above the normal water-line and which the bow especially has to turn aside as a ploughshare does the soil.

The power having now been calculated and the general features of the design sketched out, the engineers will by this time have developed their



PLAN AND ELEVATION OF MAURETANIA, SHOWING WATER-TIGHT SUBDIVISIONS AND BUNKER ARRANGEMENTS

outline plan of general arrangement sufficiently to state what space will be actually needed to accommodate the machinery. The size and position of the engine and boiler casings and stokehold ventilators, etc., will also have been mutually arranged and the bunkers planned with an eye to the economical working of coal at sea by ensuring a ready supply to the furnaces and smart bunkering when in port. An example of such an arrangement is given above.

The trim and stability calculations will be receiving attention after the centres of gravity of engines, boilers and coal, also the centre of gravity of the ship and outfit, cargo and stores have been arrived at and the curve of buoyancy adjusted to trim the vessel to an even keel when loaded. The trim will also be ascertained for entering port with, say, nine-tenths of the coal consumed, also when empty for drydocking. The first requirement having been satisfactorily met, the others will be adjusted by the use of water ballast.

The decision as to the internal arrangements is no light task, for not only has the comfort and safety of our large family to be considered, but also the economical apportioning of space to each in cabins, public rooms and promenades, as well as provision for easily working this huge hotel, in which not only is every inch precious, but where the requirements of the propelling machinery are so exacting and claim so much of our space.

It is of far more importance than appears at first sight to decide as to where this or that saloon shall be placed, and as to what is to be the exact position of and space allotted to this or that class of passengers or member of the crew.

Here again, although we must have everything as "shipshape" as possible, yet the naval architect will be amply rewarded for much time and thought spent if he hears of the appreciation of the passengers for the added characteristic of homeliness with combined comfort and artistic taste, so he will not think it waste of time to scheme cosy corners and bay windows, or design handsome fireplaces, delicately coloured panels, elaborate bathing arrangements which make the boat an ideal "hydro," skilfully placed electric lights which please because they are unobtrusive, perfected ventilation which, while keeping the atmosphere sweet and healthy, prevents draughts; telephones, which not only bring one

in touch with various parts of our floating city, but also great business centres when in port. These are details, and some would call them trifles; but trifles make perfection, and perfection is no trifle, and the boldest and most commendable projects may be spoiled by inattention to these. A "dithering" door or creaking panel, a jarring hook, an ill-ventilated cabin, may for a time so affect the passenger that all the luxuries may be unappreciated and only irritation and fretting be produced; but all these annoyances can be and have been succesfully dealt with and cured.

Ample open-air space for walking exercise, games and gymnastics have to be provided for, besides accommodation for deck chairs in sheltered nooks.

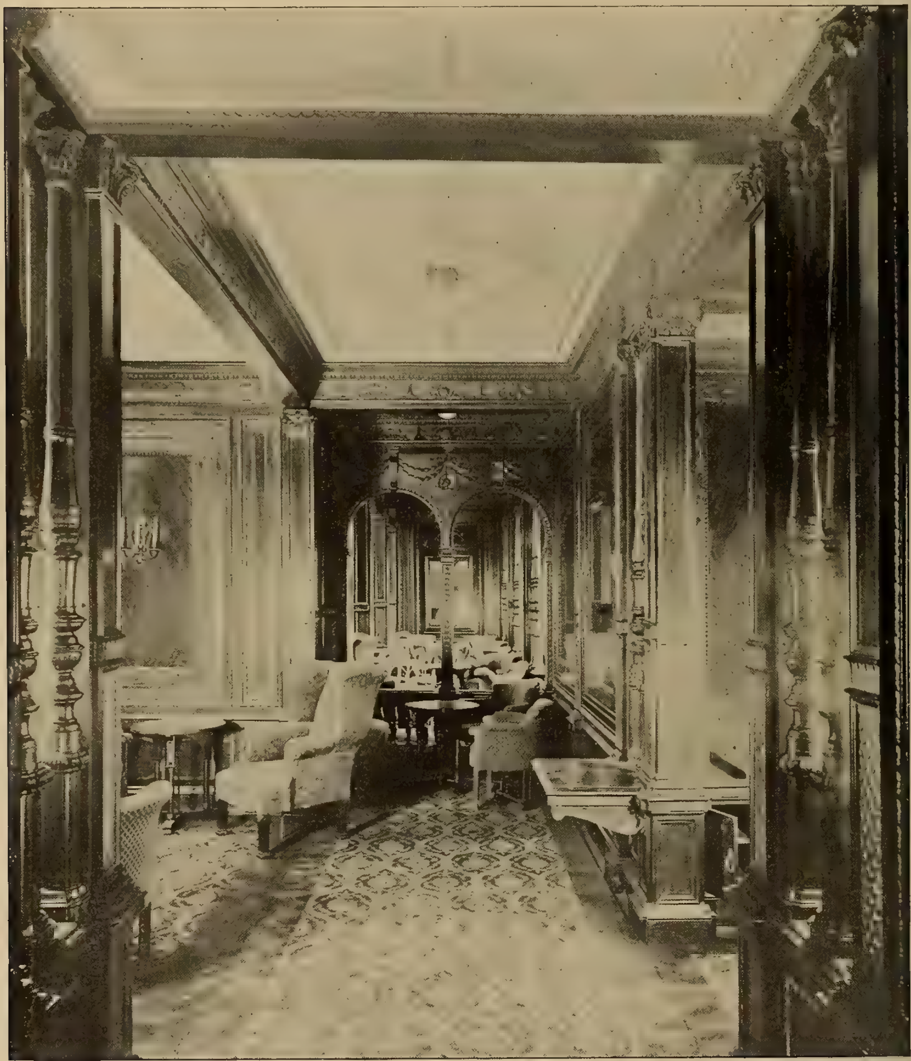
The importance of the safety of the passengers and ship's company is always rigidly kept in view when designing the structure of the ship. The highest class of passenger steamers are now so sub-divided that, should any two watertight compartments become flooded, the vessel will be safe to continue her voyage; and where it is found necessary for the efficient working of the ship to pierce watertight bulkheads, the openings have doors closed at will by automatic gear, controlled locally and from the navigating bridge by the officer of the watch. Tell-tale electric lights indicate which doors are open or closed.

MUSIC SALOON OF P. & O. COMPANY'S S. S. MOOLTAN

For additional safety, numerous lifeboats lowered by electric or steam winches are, of course, provided; but for myself I would prefer remaining on board in the event of damage to the ship.

Unless a vessel is sufficiently ventilated, whatever may be the luxuri-

ance of cabins or public rooms, she will be a failure, so far as her passenger accommodation is concerned; consequently, this subject calls for special attention at the hands of experts. The idea of ventilation solely



MAURETANIA. A NOOK IN THE SMOKING ROOM

by natural means has had to be abandoned in very fast steamers, excepting as an auxiliary, as it has been found that the natural flow of air is continually impeded or is lost to control by the exigencies of design and the course and speed of the vessel in relation to the wind. When depending upon natural ventilation continual difficulties were met with, owing to the air currents running in directions where they were not required and to their being diverted from the parts where most needed. In fact, eddies are set up by the progress of the vessel which cannot be anticipated. However, since proper systems of artificial ventilation have

been devised these difficulties have been materially lessened and, in fact, practically overcome. But it is found that, however efficacious mechanical ventilation may be, natural ventilation cannot be dispensed with. Staircases are specially helpful as aids to ventilation if made spacious and the various passages and corridors leading thereto are suitably arranged.

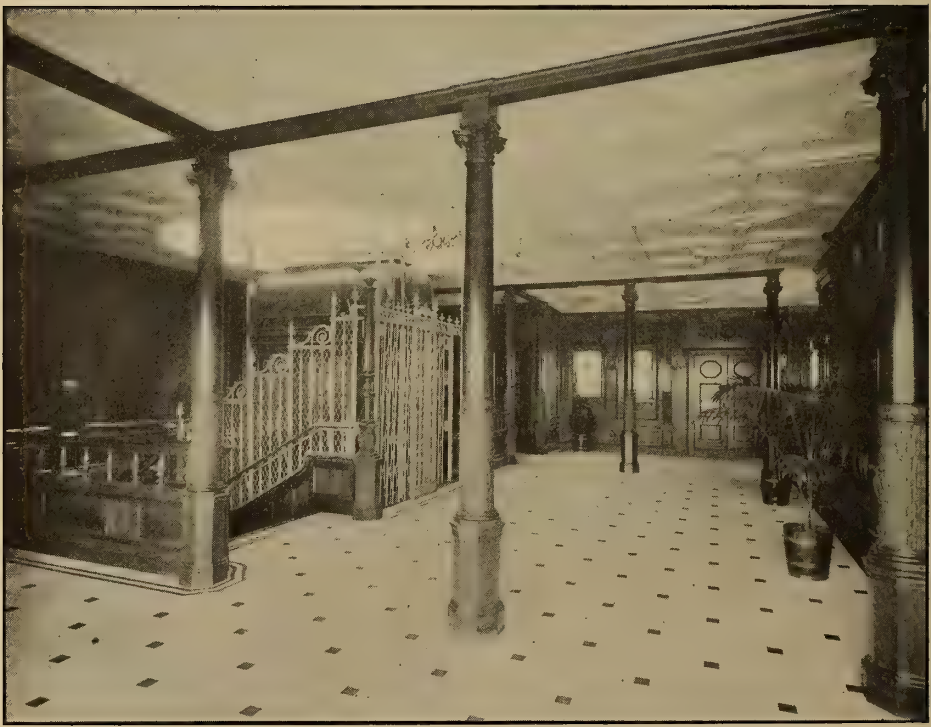
Longitudinal air ducts should be arranged overhead at each deck in such a manner that they are incorporated in the design of the cabin framing and general structure, of which they should seem to form a part—a difficult matter to accomplish, seeing that the air ducts vary so much in size and have so many ramifications, all so arranged as to ensure a continuous silent flow of air into each cabin, changing it from eight to ten times in the hour, while from the public rooms, galleys, pantries, bathrooms and lavatories the air is changed about fifteen times in the hour, preferably by exhaustions. The air is heated at will to maintain an even temperature of about 65 degrees in all weathers. The air should be humidified, say by a fine spray of steam, or the air in the cabins may be warmed by electric heaters, the temperature being automatically regulated by a thermostat.

The fans should be placed where their hum is not heard in the cabins, and the supply of air to them must be free from spray and spindrift, otherwise it will find its way into ducts and eventually into the cabins with disastrous results. To secure this, shielded inlets are placed in protected positions and at as great an elevation as practicable.

DINING SALOON OF HOLLAND-AMERICAN LINER ROTTERDAM

By this time we have before us the complete designs of the ship, busy brains and skilled hands have been at work, and we have little to fear as to the result when the plans and designs have been reproduced in metal and wood. Her trial trips and sea results will demonstrate how accurately everything can be calculated

MAURETANIA BEING COMPLETED AT THE WALLSEND SHIPYARD



GRAND ENTRANCE, STAIRCASE AND PASSENGER LIFT OF THE MAURETANIA

before a plate is punched or a plank sawn.

If the margin of power has from necessity been kept very low on account of weight or there should be any doubt as to the steaming results, it would be advisable, if time permits, to test the model experimentally to check the calculated effective power; but for a vessel of the contemplated size and speed it is not anticipated that this will be really necessary, as she is not an extreme case, there being larger and faster vessels actually at work in the North-Atlantic service, the steaming results of which are doubtless sufficiently well known to the designer.

After checking and developing the foregoing approximate figures the lines and even dimensions may have to be slightly amended, after which a half model will be proceeded with, say to a scale of ¼ inch to the foot. After approval, "laying off" is commenced and the form of the vessel developed to full size for purposes of construction, and the frame spacing, decks, bulkheads and shell lines will be marked off on the model. In the meantime the necessary calculations will have been made, so that the scantlings may be specified and marked on the drawings of the midship section, profile and deck plans. The principal forgings and castings also have been designed and the whole submitted to the Classification Society for approval. The general arrangement plans of the vessel will now be developed more closely, and the detail plans for the joiners, carpenters, upholsterers, plumbers, coppersmiths and riggers, etc., will be put in hand in due course and the whole work pushed forward in every department.

TURBINE STEAMER HELIOPOLIS, ILLUSTRATING HEIGHT OF DECK HOUSES

In many large vessels the general

arrangement plans are drawn first to a scale of 1/16 inch, so that the eye may readily grasp the features of the design and detect any want of harmony in the arrangement, after which they are drawn more in detail to a scale of $\frac{1}{8}$ inch to $\frac{1}{4}$ inch.

It will be interesting to note that, by the time the vessel is completed, about 4,000 plans and copies will have been produced in the shipyard drawing office, irrespective of those made by the engineers and sub-contractors.

By the foregoing it will be readily conceded that the structural and general arrangements for a fast ocean steamer will entail a very large amount of labour in organization and the responsibility in the design and construction, as vessels of this class are not only sumptuous hotels for the accommodation of anything up to 2,000 guests, but are also most complex structures, having to resist forces opposing their progress inch by inch—forces which cannot be realized by any but those who have experienced a North-Atlantic gale.

Probably the reader will have been impressed with the elaboration and expenditure necessary for the production of such vessels, yet he will doubtless be still more impressed by the fact that the result in the aggregate has tended to considerably reduce the cost of travel, seeing that the passenger rates are so remarkably low, the first class averaging per mile about half that charged for a passage in the *Britannia* in 1840. The passage money for vessels of this class works out at about $1\frac{1}{2}d$ per mile for a first class passenger, $\frac{3}{4}d$ per mile for the second and 0.4 of a penny for the third class. It is marvellous and extraordinary!

As one's thoughts dwell upon the swiftly developing science of naval architecture, one naturally begins to speculate as to what the future holds in store. He would be a bold prophet indeed who attempted to dogmatize as to what even the next decade will reveal; but with further experience in the use of high-tensile steel, internal-combustion engines adapted to bituminous coal or crude petroleum, water-tube boilers and turbine engines, combined with the results of the labours of experimentalists on towed and self-propelled models and trained observers at sea, some of the present difficulties and problems will doubtless be speedily solved and fields for the energy and enterprise of owners, builders and engineers of fast ocean steamers be extended far beyond our present vision.

THE GIANT ORE CARRIERS ON THE GREAT LAKES

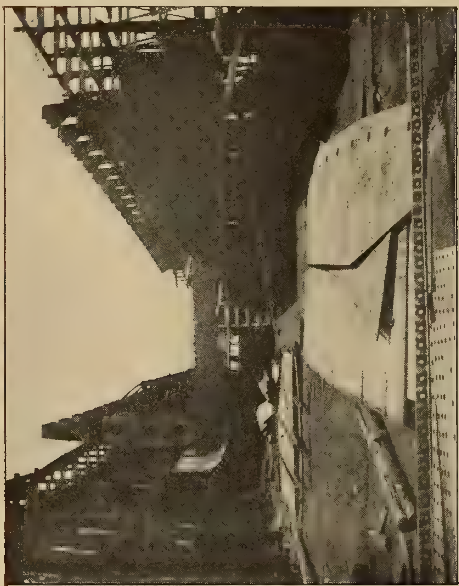
By James Cooke Mills

THOSE good citizens of the United States who are worried over the disappearance of the flag of the American merchant marine from the seas should find some consolation in the fact that considerably more than one-third of all the American tonnage is represented by the Great Lakes shipping, and that the lake tonnage has increased 69 per cent. in the last ten years. More than one-half of the tonnage constructed during the past year was on the lakes, and of the fifty-odd vessels of various types put into fresh water, with an aggregate tonnage of nearly 300,000, fourteen were giant ore carriers, from 600 to 606 feet in length, 58 feet beam and 32 feet moulded depth. The cargo capacity of these ships is close to 20,000 tons of ore or coal on a draught of 24 feet; but as the present channels in the Detroit River, the St. Clair ship-canal and the long rock-cuts of the St. Mary's River give a maximum depth of only 20 feet, their capacity is reduced to about 14,000 tons, or, in the grain trade, to about 400,000 bushels.

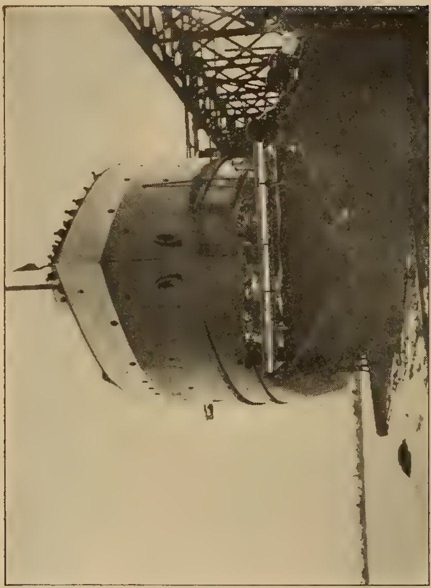
The steamer *Daniel J. Morrell,* with a length over all of 602 feet, is representative of this type, and in a single voyage carries a cargo equal to the combined capacity of every boat of every description that floated on Lake Superior at the beginning of the Civil War, including every steamer, every sailing vessel, every barge, every bateau and every canoe. On the day the *Morrell* was launched her captain, who had been detailed by the owners to bring her out, stated that it would require every regular trip of the first steamer he commanded twenty years before for two and a half years to carry from Duluth to Cleveland as much ore as would be carried by the new freighter on her first trip.

The American people have little realization of the enormous traffic of these inland seas, and even the inhabitants of the lake States and of the Middle West may be surprised to know that the commerce of the Great Lakes now amounts to one hundred million tons yearly, all of which is carried in a navigation season of about 240 days. Figures dealing with statistics are cold evidences of fact at best, and generally give but vague ideas as to volume and extent. If those who seek the more convincing evidence of sight could spend a few hours on the wharves along the Detroit river front, which faces the world's greatest water highway, they would witness the finest parade of shipping to be seen on the continent. They would look upon two processions, one moving up, the other down the stream, almost without interruption, and representing the greatest traffic, in tonnage and in value of the freight, that traverses any marine highway in the world. If the observers chose a day in the height of the navigation season for their object lesson and remained at their post for twelve hours, they would see as many as 110 ships, or even more, of various types and all of the utmost interest, passing in the busy stream on an average of one vessel every six minutes of the time.

In a single season of navigation the number of passages reported was nearly 38,000, more than ten times as many as recorded for the Suez Canal,



THE KEEL, RIBS, AND UPRIGHTS, TWENTY DAYS AFTER LAYING THE KEEL



THE CHARLES WESTON, ONE MINUTE BEFORE LAUNCH. PARTY ON STAND, EVERYTHING READY

THE MORRELL TEN MINUTES BEFORE THE LAUNCH. THE CRADLES ARE PLAINLY SEEN

THE CRITICAL MOMENT. DIPPING IN HER NATIVE ELEMENT

while the aggregate of the cargoes exceeded sixty-seven and a quarter million tons, an amount far greater than that borne by all the ships, British or foreign, entering the ports of Great Britain in an entire year. It also exceeded the total merchandise entering the harbours of New York, Boston, Philadelphia, Baltimore, Charleston and Savannah combined. The lake shipping that year effected a saving to commerce of $89,000,000, represented by the difference between the lake rates and the tariff exacted by the railroads.

LOOKING THROUGH THE LENGTH OF STEEL SKELETON, SHOWING DOUBLE SIDES, THE FRAMES SLOPING UPWARD, FORTY DAYS AFTER LAYING OF KEEL

To transport such a vast quantity of freight, made up largely of coarse, heavy commodities, such as ore, coal and grain, ships of special and unique types, as viewed by seafaring men, have been evolved. The lakes have presented their own peculiar problems to the navigator, and the naval architect, breaking away from the traditional forms of sea-going ships, has produced new ones better adapted to the needs, but of rig, shape and proportions calculated to stir the blue-water sailor to astonishment or scorn. Nevertheless, the 600-foot ore-carriers and numerous other smaller ships of similar proportions and design are better suited to the requirements of the lake service than any other type of ship would be. The long sweep of deck, clear of spars and superstructure and pierced with hatches from one end to the other, admits of the utmost rapidity in taking and discharging cargo. With an ore chute delivered at each of her twenty-four to thirty-six hatchways, the largest ship can be loaded in two hours, while five to ten hours' work with the huge "clamshells" will clear her hold. There are no sailors on the lakes to-day, for everything is done by special machinery, invented and introduced within the last three or four years, requiring for operation anywhere from thirty to forty machinists and firemen. The ore docks built especially to accommodate the new ships are equipped with

rapid-handling machinery of the latest type, and so keen is the rivalry between them that new records have been established time and time again, only to be broken the following month by some other dock. At Duluth one of the huge ore carriers took in 9,277 tons of ore in seventy minutes, which is at the rate of 8,000 tons an hour. How long these figures will stand no one can tell, but they illustrate the progress of one phase of the lake shipping.

In designing the leviathans of the lakes the chief problem is to provide requisite strength, considering at all times the disproportion existing between the length and beam and the slight depth of hold, rendered necessary by the shallow channels of the connecting rivers. All the earlier principles of shipbuilding have been ignored by the marine architects of to-day in giving a ship 600 feet in length and with 58 feet beam a depth of only 32 feet. The constructors have had to bear in mind the quick, choppy seas raised by the gales of the upper lakes, in which the strength of the big ships is severely tried. These storms are often of terrific violence, and as there is no room to run before them, as can be done at sea, a ship must bear the stress of it and fight it out. At such times a loaded freighter's waist will be awash with green water fore and aft, while her whole frame is twisting and groaning under the tremendous strain. One without a cargo to lend rigidity is in a situation graver still, and on one occasion a leviathan, after battling with a storm on Lake Huron, found, on reaching a harbour of refuge, that the working of her plates had cut thousands of the steel rivets fastening them together, and several hundred pounds of the rivet-heads were taken from her hold. A few more hours of the struggle would have sent her to the bottom.

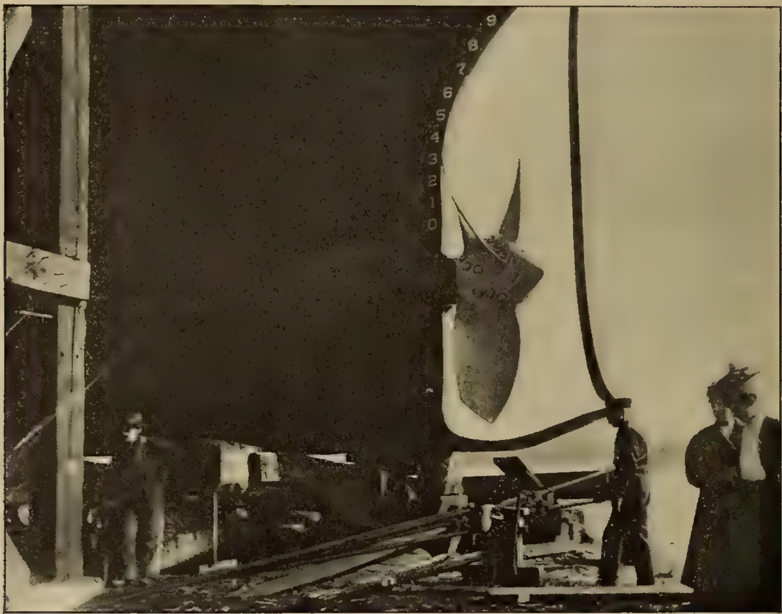
VIEW SHOWING THE ARCHED GIRDERS BEING PUT IN AND ARM OF CANTILEVER CRANE. PERFORATED RIBS ARE ALSO TO BE SEEN IN FOREGROUND. TWO MONTHS AFTER KEEL WAS LAID

Profiting by the experience of the earlier builders of steel ships for the

CHARLES WESTON, 12,000 TONS; WILLIAM B. KERR, 13,000 TONS, LYING AT ANCHOR AT DETROIT

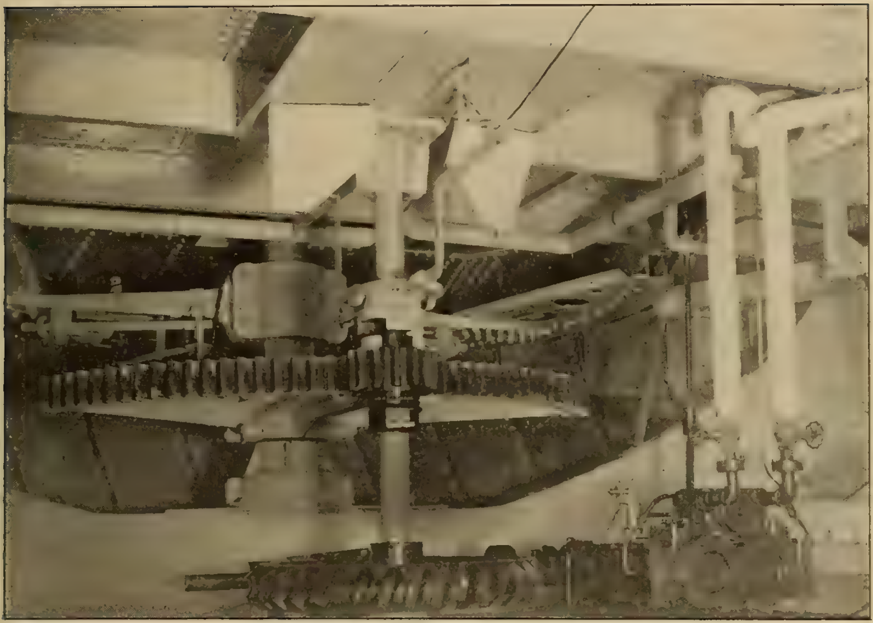
LOADING THE LEGRAND S. DEGRAFF WITH COAL AT LORAIN, OHIO. A 100-TON CAR IS PICKED UP BODILY AND DUMPED THROUGH THE HATCH IN THREE MINUTES

lake service and by the behaviour of the freighters in the 500-foot class, the constructors have evolved a type of ore ship entirely lacking the defects of structural weakness inherent in previous vessels of such proportions, and still retaining the desirable qualities of stability and speed. The last requisite of a successful model has been secured with but a slight increase in horse-power over the 400-foot class, and the 600-footer requires but few more hands to man her. With a rate of 70 cents per ton from Lake Superior to the Erie ports, the temptation to build to the limit of structural stability is a reasonable one. Many vesselmen, however, believe that the limit has been reached, and that the 606-foot leviathans on the Great Lakes will hold for many years the proud title of the "largest coarse freighters in the world." This is a fair prophecy, and will probably prove true, at least until the government provides a clear channel of 24 or 25 feet through all the waterways of the Great Lakes.



VIEW OF THE UNDER STERN; SHOWS SCREW 12 FEET IN DIAMETER. ALSO THE TRIGGER AND LINE ACROSS THE BLOCK, AND AXE AT HAND TO CUT IT WHEN SIGNAL IS GIVEN

The construction plans and specifications for these ships, showing every detail of the work, are of exceeding interest, and are a revelation in present-day methods. Reference to the illustrations makes clear the principal features of construction by which the maximum of structural strength is secured and with the sacrifice of but little cargo space. As a first consideration, the keel is of unusual proportions. It is built of sheet steel, forming a continuous plate girder 580 feet long by 6 feet 3 inches deep, thus providing between the outer and inner bottoms a space of sufficient height for a tall man to stand erect. This space is divided into numerous small compartments by the ribs, which are riveted to the keel on both sides at intervals of a few feet. Certain groups of these ribs are perforated with large holes to permit the passage of water to ballast the ship when running light. Other ribs are left solid to form water-tight compart-



THE AKERS EMERGENCY STEERING GEAR, USED ON MANY LAKE STEAMERS. CAN BE PUT INTO ACTION INSTANTLY IN CASE OF FAILURE OF REGULAR STEERING ENGINES

THE CITY OF CLEVELAND. THE LARGEST PASSENGER STEAMER ON THE GREAT LAKES. COST $1,250,000. EQUIPPED WITH A BOW RUDDER AND FITTED WITH THE AKERS EMERGENCY STEERING GEAR. CAPACITY, 4,000 PASSENGERS; DESIGNED BY FRANK KIRBY

LEGRAND S. DEGRAFF, WILLIAM M. MILLS, WILLIAM B. KERR, SISTER SHIPS, 607 FEET LONG, 60 FEET BEAM, 32 FEET MOULDED DEPTH

Carrying capacity, at 19 feet draught, 13,000 tons of ore or coal, or half a million bushels of wheat. Capacity at 21 feet draught, 16,000 tons. The largest freighters on the Lakes. Owned by the Weston Transit Company, North Tonawanda, N. Y. Speed, 12 miles per hour.

ments, any one of which can be filled and emptied entirely independent of the others. Throughout the midship section and extending forward and aft to within about a hundred feet of the bow and stern the bottom is flat, and then rounds up rather bluntly. The upright frames are of angle-bar construction, and form a double wall or sides for the ship for about half their length, sloping easily to a point above at the beginning of the curve of the arches.

The third feature providing added strength and rigidity to the ship is the common use of the arched girder, placed above and binding in their stiff grip the upper ends of the uprights, and also forming rigid supports for the main deck with the hatchways between them. The ribs, uprights and arches are all constructed on the ground or in the moulding shop, and as fast as they are completed they are hoisted into place by the cantilever crane. The various parts are temporarily secured in place by bolts; but riveting gangs follow close after the erecters, and the continual tapping of the pneumatic riveting machines testifies to the progress of the work. The plates which sheath the frame are made of ⅝ and ¾-inch mild steel, and after being cut and shaped to conform to the rounded form of the ship, the rivet holes are punched in exactly the right places to fit the holes previously drilled in the ship's frame. They are carried from the shop to the steel skeleton out in the yard by locomotive cranes, hoisted in place, bolted and riveted fast in the same manner as the component parts of the frame are secured together.

In order to secure the maximum of cargo space the propelling machinery is placed in a separate water-tight compartment in the extreme stern of the ship, the bulkhead between the machinery and cargo holds being constructed with special regard to strength and rigidity. The boilers, engine and much of the auxiliary ma-

chinery is here installed very compactly, allowing ample room for coal bunkers and oil and supply chests. The engine is of the vertical, triple-expansion, screw-propelling type, developing 2,200 horse-power at 120 revolutions per minute. The cylinders are 24, 39 and 65 inches in diameter by 42 inches stroke of piston, and are supplied with steam at 180 pounds pressure from two Scotch boilers fitted with Eaves and Ellis forced draught. The boilers are each 15 feet in diameter by 12 feet long, weighing nearly 100 tons each. The normal economic speed is between eleven and twelve miles an hour on load draught. With no unusual delays, such a freighter will make thirty trips from Duluth to Buffalo, a distance of 1,000 miles, in a season, transporting nearly 400,000 tons of ore. The ships of the Pittsburg fleet (the United States Steel Corporation), more than one hundred in number, return to Duluth in ballast, although some of the big fellows belonging to independent companies carry coal on the return trip, making about twenty round trips in a season.

The ship is well equipped with auxiliary machinery, comprising steam steering gears, steam winches and hoists, pumps and an electric lighting plant. The wheelhouse, the captain's and mate's cabins are located in the extreme bow, and are finished in mahogany and luxuriously furnished. The flagship of the fleet and generally two or three others are fitted with an extra cabin and staterooms to accommodate the owners and friends, for a "trip up the lakes on a freighter" is "quite the thing." The crew is comfortably housed in a large cabin on the quarter deck. Telephones connect the wheelhouse, the captain's and owner's cabins and the engine room and crew's quarters, and every other device for convenience and comfort is provided on the lake giants of to-day.

THE JAMES CORRIGAN, 10,000 TONS, ON THE STOCKS JUST BEFORE LAUNCHING

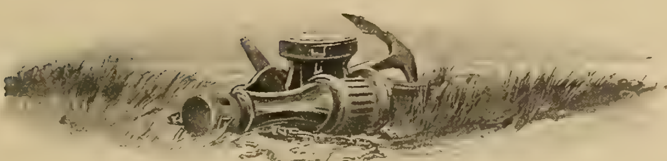
LAUNCH OF THE JAMES CORRIGAN, SISTER SHIP TO THE DANIEL B. MEACHAM

On the Great Lakes it is the universal practice to launch vessels sideways instead of stern first; therefore the ships are built parallel to the stream or slip and at the very edge. Under the ship at intervals of 8 or 10 feet are heavy oak timbers sloping back from the edge of the stream at an easy angle, to form the ground ways. Early in the morning of the day the ship is to be launched hundreds of the workmen are building up the cradles under the ship, their base resting on the smooth ground ways, which are well greased with tallow. The tops of the cradles, consisting of 12-inch timbers 12 or 14 feet long, placed crossways of each other, bear up against the bottom of the ship. When all the

LAUNCH OF THE DANIEL B. MEACHAM, BEFORE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AT DETROIT

cradles are ready wedges are driven home, lifting the huge hull slightly, and the shores and blocks upon which the ship has rested during construction are knocked away.

The ship now resting on the cradles, and they on the greased ways, would slip at once into the native element but for checks placed at stem and stern. These checks are five stout lines secured at one end to triggers holding the cradles to the ground ways, the other ends running back over a flat timber and drawn taut by block and tackle. With the Stars and Stripes and the ship's burgee floating in the breeze, the launching party and the ship's sponsor arrive on the scene. Everything being in readiness for the final act, the signal is given. Five axes in the hands of brawny men on the ground below and as many at the stern come down on the lines, they are cut through by the single blow, the triggers snap back with a sharp crack, and the big ship is free. For a second or two it hesitates, as if to make up its mind whether it wants to be launched or not. Then, with a shudder and a crunching of timbers, it starts slowly, the bottle of champagne is shattered on the bow, the christening words are spoken, and the huge, bulky mass slides down the short ways, careening slightly, and plunges into the stream. A mighty wave, almost as high as the sloping deck, rises and sweeps across the river and dashes itself on the docks beyond. The ship rights quickly and is towed to the fitting-out dock beside the great shears, which in a day or two hoists the boilers and engine into the hold. If all goes well, the machinery is installed and finishing touches done in thirty days, and the ship steams away for a trial trip. The machinery will be stiff and some journals will run hot; but the maiden trip is soon undertaken, on a day only about 140 days after the initial work was begun—the laying of the keel. The entire cost of the ship has been $540,000. On her first trip from Escanaba to Chicago down Lake Michigan the cargo of ore was 15,081 net tons on a draught of 20 feet 6 inches, a record for the time.



THE DEVELOPMENT OF THE MODERN MARINE ENGINE

INCLUDING A REFERENCE TO WATER-TUBE BOILERS

By J. W. Reed, M. I. N. A., M. Inst. M. E.

IN dealing with the subject of the modern marine engine it appears to be quite appropriate to look back a few years and review briefly some of the steps that have led up to the present stage of development.

Although the triple-expansion engine has been fitted, in isolated cases, for some years earlier, it is something like twenty-four years since it took a thorough hold of the mercantile marine.

No doubt the advance in the manufacture of steel boiler plates contributed largely to its easy introduction, enabling, as it did, the higher steam pressures to be carried without abnormally heavy boilers.

The results obtained exceeded the most sanguine expectations, the cessation of the general manufacture of compound or double expansion engines was very abrupt, and for many years a large amount of work was created by the haste with which shipowners had their compound engines converted to triples or replaced by new triples. As an instance, the first two triple-expansion engines built by the writer's firm actually replaced simple jet-condensing engines operating at 30 pounds pressure, the new engines using 150 pounds pressure.

The desire to get the three-cylinder engines into the same space as the old two-cylinder engines led to quite an epidemic of valve gears of varying degrees of efficiency, some with quite a wonderful amount of complication. Gradually, however, these nearly all disappeared, and the ordinary Stephenson link motion has survived as the standard gear.

The pressure adopted at the introduction of the triple-expansion engine in merchant vessels was generally about 150 pounds per square inch, and this remained the standard for a considerable time; but gradually the pressure was increased, until at the present day 180 pounds per square inch more nearly represents the standard. There are, however, many vessels fitted with triple engines working at 200 pounds per square inch.

The phenomenal success of the triple-expansion engine soon led to the introduction of the quadruple-expansion engine; but with the moderate pressure of 180 pounds per square inch then adopted the progress was slow, as the possibilities of any large saving were limited. The change from compound to triple was accompanied by a fall in the rate of coal consumption of about 20 per cent., from about 2 pounds to about 1.6 pounds per indicated horse-power per hour, or about four-tenths of a pound reduction. In the case of the quadruple-expansion engines there was thus a much lower figure to start from, as compared with the triple; and the pressure being no higher than is now common for triples, 5 per cent. was probably a fair statement of the saving, or barely one-tenth of a pound per indicated horse-power. This small advantage, together with the increased number of cylinders and parts, retarded its advancement, especially in low-powered vessels.

Higher pressures were adopted later, and now for quadruple-expan-

sion engines the pressure is seldom less than between 210 and 220 pounds per square inch, and in some cases it is as high as 267 pounds per square inch, even with cylindrical boilers. The quarduple-expansion engine is now largely fitted in the higher-powered vessels, and there the question of having four cylinders and corresponding parts does not appear as an objection; for in such vessels four cylinders would, in the majority of cases, be fitted even with triple engines, so that the saving in coal appears as an advantage, without any more serious set-off against it than extra initial cost. This saving, however, can scarcely be put down at more than 7½ per cent.

In the triple engine with the modern pressure of 180 to 200 pounds per square inch, and the combination of Howden's system of forced draught with heated air-supply, the consumption of good coal has fallen to 1.5 pounds per indicated horse-power per hour on the voyage, and in many reliable instances to less; whilst in the quadruple the consumption is about 1.4 pounds, with also a number of instances in which it is down to 1.3 pounds. The British Boiler Committee's trial of R. M. S. *Saxonia* for a period of thirteen hours gave a consumption of 1.29 pounds per indicated horse-power per hour.

In recent years there has not been any great change in the general design of the triple or quadruple-expansion engine. There has, however, been a great increase in the power put into the Atlantic liners, and with this increase of power the fitting of twin screws has become practically a necessity.

Ten years ago 30,000 indicated horse-power, as fitted into the *Campania* and *Lucania,* also in the *Kaiser Wilhelm der Grosse,* represented the most powerful installations; but with reciprocating engines we have, in recent years, engines of 40,000 to 45,000 indicated horse-power, as represented by the *Kaiser Wilhelm II.* and *Kronprinzessin Cecilie.*

With the building of the *Campania* and *Lucania* British efforts to hold the blue riband of the Atlantic seemed to pause for a time, whilst the German-built vessels secured and held it, and year after year passed without any competitor.

The engines of the two German vessels above referred to are fine examples of modern engineering, and reflect great credit on their designers and builders. These engines drive twin screws, and consist of four sets of quadruple-expansion engines, two sets to each line of shafting. They are three-crank engines; but each set has four cylinders, the high-pressure cylinder being placed tandem to the first intermediate. The high-pressure cylinder is 37.4 inches in diameter, the first intermediate 49.2 inches, the second intermediate 74.8 inches, and the low-pressure cylinder 112.2 inches in diameter, all with a stroke of 70.8 inches, with a piston speed of about 950 feet per minute. Steam is supplied by twelve double-ended and seven single-ended cylindrical boilers working at 225 pounds per square inch.

In war vessels the triple-expansion reciprocating engine has remained the standard until superseded by the turbine. The engines of H. M. S. *Orlando* are believed to be the first triple-expansion engines fitted in the British Navy. The order was originally placed with the Palmers Shipbuilding & Iron Company for compound engines; but before any work was commenced in the shops it was decided to adopt the triple-expansion type, which had at that time taken a firm hold of the mercantile marine. These engines were horizontal and with three cranks. The cylinders were 36 inches, 52 inches and 78 inches diameter, with 42 inches stroke, with a piston speed of 800 feet per minute. The working pressure was only 130 pounds per square inch, which was only a small increase over the pressure for the previous compound engines of 110 pounds per square inch. The indicated power for

the two sets was 8,700 horse-power.

The adoption of the triple-expansion engine in the British Navy was of a wholesale character, and very soon after the step was taken the vertical engine took the place of the horizontal. The adoption of the vertical engine paved the way for a gradual increase in the number of revolutions and piston speed, while at the same time there was a general increase in the amount of power put into war vesels.

In 1887 a first-class cruiser of 8,500 to 9,000 horse-power had horizontal engines and a piston speed of about 770 to 805 feet per minute, with 110 to 115 revolutions per minute; whereas in the cruisers of 9,000 horse-power with vertical engines, immediately following, the piston speed was 910 feet per minute, with 140 revolutions per minute.

In the latest of the cruisers with reciprocating engines the power had risen to 30,000 horse-power and the piston speed to 960 feet, with 120 revolutions per minute, the engines having four cylinders.

In smaller cruisers of the *Sapphire* class of about 10,000 horse-power the piston speed was 1,000 feet and the revolutions 250 per minute; and in torpedo-boat destroyers of the 30-knot class the piston speed has, in several cases, exceeded 1,200 feet per minute, with over 400 revolutions per minute. In the later reciprocating engines for destroyers the speed was kept under 1,200 feet, being about 1,150 feet per minute.

In these high-powered engines with comparatively high rate of revolutions, both in the mercantile service and in naval vessels, the question of the effect of the moving parts on vibration became an important matter, and with the four-crank design many engines are balanced on the Yarrow-Schlick-Tweedy system, where the disposition of the cylinders, the weights of the moving parts and the angles of the cranks are so adjusted as to reduce the vibratory effect to a minimum, if not entirely eliminate it.

At the same time, with the ordinary arrangement of cylinders and a slight adjustment of the crank angles a very satisfactory balance can be obtained in most cases without the necessity of specially adjusting the weights of the moving parts, in fact quite sufficient for all ordinary cases, and some of the recent battleship engines are so balanced.

With the three-crank engines having cranks spaced 120 degrees apart no special provision is made for further balance, except in those at the higher rates of revolutions, over about 200 revolutions per minute. In these it is usual to attach balance weights to the cranks to balance the revolving weights and the whole or part of the reciprocating weights.

In the case of torpedo-boat destroyer engines with forced lubrication, balance weights were fitted to all three cranks. The method there adopted has been uniformly applied to the whole of the twenty-five torpedo-boat destroyers built by Palmers Company, commencing with the *Janus,* in 1895, which at that time stood out prominently amongst the 27-knot destroyers as being exceptionally free from vibration. The same method was applied to several torpedo gunboats and third-class cruisers. The balance weights on the centre cranks were merely equivalent to the revolving weights, whilst those on the end cranks were equivalent to the revolving weights together with the reciprocating weights, the angular positions of the centre of gravity being carefully disposed to suit these various weights.

The practical result was that there was not the slightest vertical vibration, even at the stern, and no appreciable horizontal vibration—nothing more than a slight tremour, which only registered, on Professor Milne's vibration recorder, less than one-thirty-second of an inch.

The highest speeds of revolutions are almost invariably found in war vessels, and the necessity for some more positive system of lubrication

than the ordinary has long been felt. This was particularly emphasized in the case of torpedo boats and torpedo-boat destroyers, and in 1900 one of the British 30-knot torpedo-boat destroyers (the *Syren*), ordered from Palmers, had the main engines fitted with forced lubrication on the Palmer-Reed system.

This was the first set of engines so fitted in the British Navy, and the smooth running of the machinery and the general improvement in working due to this system quite exceeded all expectations, and was so satisfactory on a lengthened trial in regular service that the last three of the river class of torpedo-boat destroyers ordered from Palmers Company were fitted in the same manner. These again on service maintained the reputation for being far ahead of the ordinary type, and gave such satisfaction that it is probable that some such system of forced lubrication would have become the regular practice in destroyer and torpedo-boat work had not the reciprocating engine been superseded by the turbine.

With these engines the whole of the working parts, with the exception of the back air-pump links, are cased in.

A pair of oscillating oil pumps at the end of the shaft force the oil through the centre of the crankshaft, whence it flows to all the bearings of the engine, falling back into the crank-pit and flowing to the oil pumps. The oil level is kept low enough to prevent connecting-rods or cranks splashing into it.

ENGINES OF H. M. S. SENTINEL, CONSTRUCTED BY VICKERS, SONS AND MAXIM, LTD., BARROW-IN-FURNESS

The casing is provided with a number of windows, and the interior is lighted up by several electric lamps, thus enabling the condition of the various parts to be readily seen, while by opening any of the lower windows the temperature of the oil thrown off can be felt.

In large engines of battleships and cruisers the latest British ships with reciprocating engines have been fitted with a system of forced lubrication

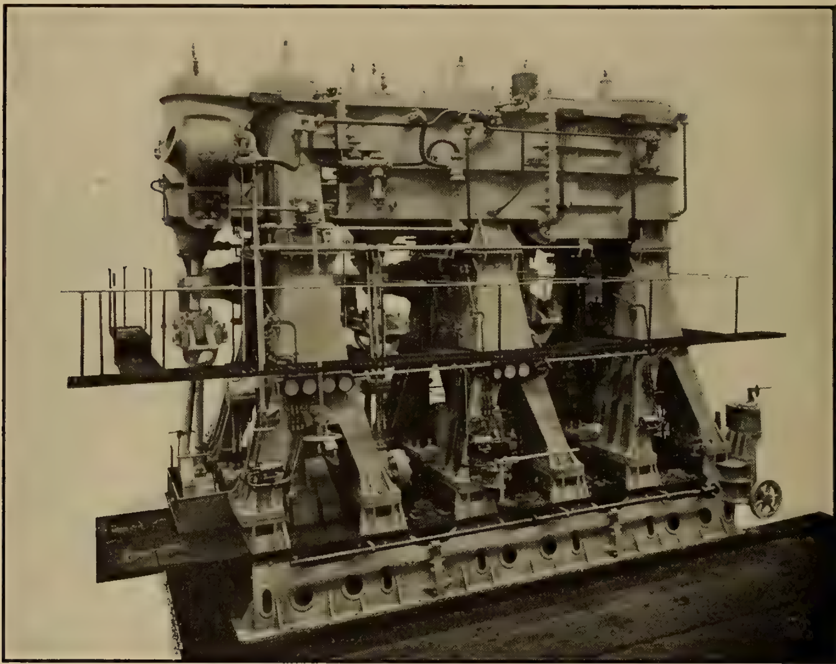
to the principal bearings, and with thoroughly satisfactory results, both as to certainty of continuous running at high speed and reduction of engine friction.

Any engineer familiar with the running of high-speed engines in battleships, cruisers and destroyers under the usual conditions of lubrication with even the necessary moderate use of the water service and the consequent spraying of oil and water in all directions, will thoroughly appreciate the conditions of the trials under the forced lubrication systems, when not a drop of water is allowed to be used and the necessary protecting casings prevent any oil from being thrown about, overalls, let alone oilskins, being superfluous.

Further, the fine adjustments which accompany these systems produce a very smooth and quiet-working engine, while the wearing of the bearings is reduced to a minimum.

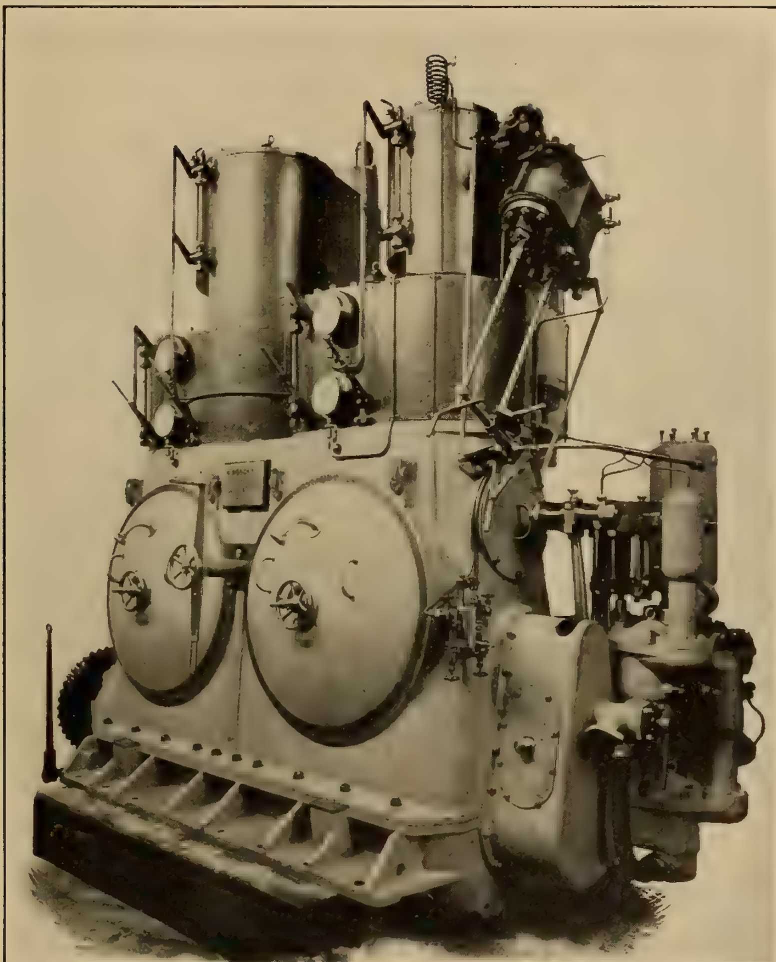
It has frequently been said, and possibly with a considerable amount of probability in it, that had forced lubrication for the engines of destroyers, cruisers and battleships been adopted earlier, it would have made a considerable difference in the rapidity of the adoption of the turbine in war vessels.

The engines of H. M. S. *Lord Nelson* were built and engined by Palmers Company. The engines are of the four-crank, triple-expansion type. The high-pressure cylinders are 32¾ inches in diameter, the intermediate 52¾ inches, the low-pressure cylinders 60 inches in diameter, and the stroke 48 inches. The working pressure of the boiler is 275 pounds per square inch for about 250 pounds at the engines. These are fitted with forced lubrication to the principal bearings. The total power is 16,750 horse-power, which was maintained with exceptional ease on the trials. There is, perhaps, a certain amount of senti-



STARBOARD ENGINE OF TROOPSHIP DUFFERIN, CONSTRUCTED BY VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS

mental interest attached to these engines, as they are the last of the reciprocating type of triple-expansion engine to be supplied to the British Government for war vessels, and it is a coincidence worth recording that what are believed to be the first



ENCLOSED ENGINES OF THE STEAM YACHT VAGRANT, MADE BY W. SISSON & CO., GLOUCESTER

triple-expansion engines for the British Navy were built by Palmers Company for H. M. S. *Orlando,* as already referred to.

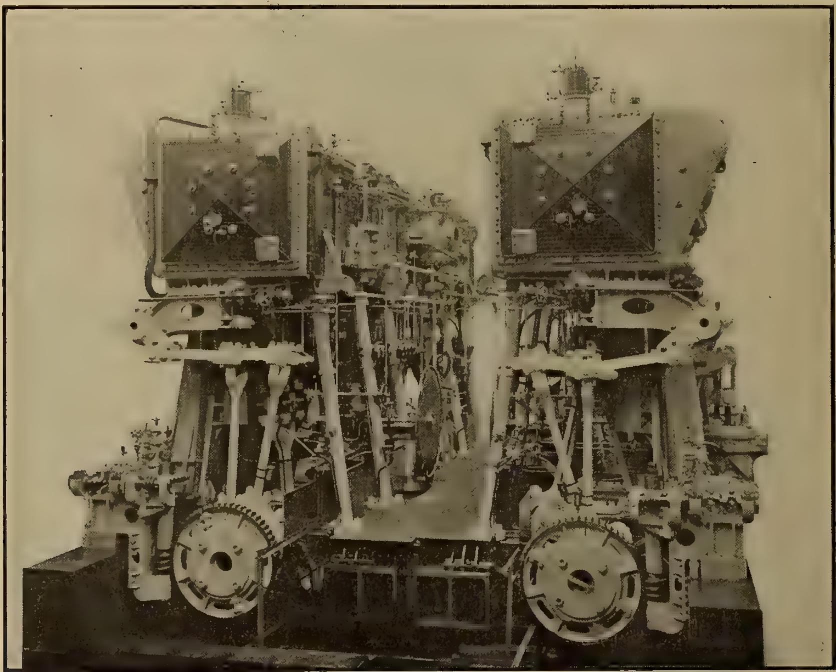
In the merchant service little has been done with regard to fitting automatic lubrication, except for smaller-sized machinery. One instance may be given: the machinery for the steam yacht *Vagrant,* built by Palmers Company for Charles Markham, Esq., was fitted with Sisson's patent four-crank, triple-expansion engines, with all working parts enclosed and self-lubricating. The cylinders are: One high-pressure, 14½ inches diameter; intermediate, 24½ inches diameter, and two low-pressure, 24½ inches diameter, all with 13½ inches stroke.

Amongst the examples of modern British engineering may be noted the engines of H. M. cruiser *Antrim,* H. M. battleship *Africa,* engines of

the Cunard Company's T. S. S. *Caronia,* and those of the T. S. S. *Duke of Connaught,* constructed by Messrs. John Brown & Co., Ltd., Clydebank.

The engines of the *Antrim* are two sets of four-cylinder, triple-expansion type, each having one high-pressure cylinder 41½ inches diameter, one intermediate cylinder 65½ inches diameter, and two low-pressure cylinders 73½ inches diameter, with a common stroke of 42 inches. They are together capable of developing 21,000 horse-power when working at 140 revolutions per minute. Steam at 210 pounds pressure is supplied by seventeen boilers of the Yarrow type and six boilers of the cylindrical, return-tube type, all of these working with closed ashpits and heated air-supply on the Howdon system.

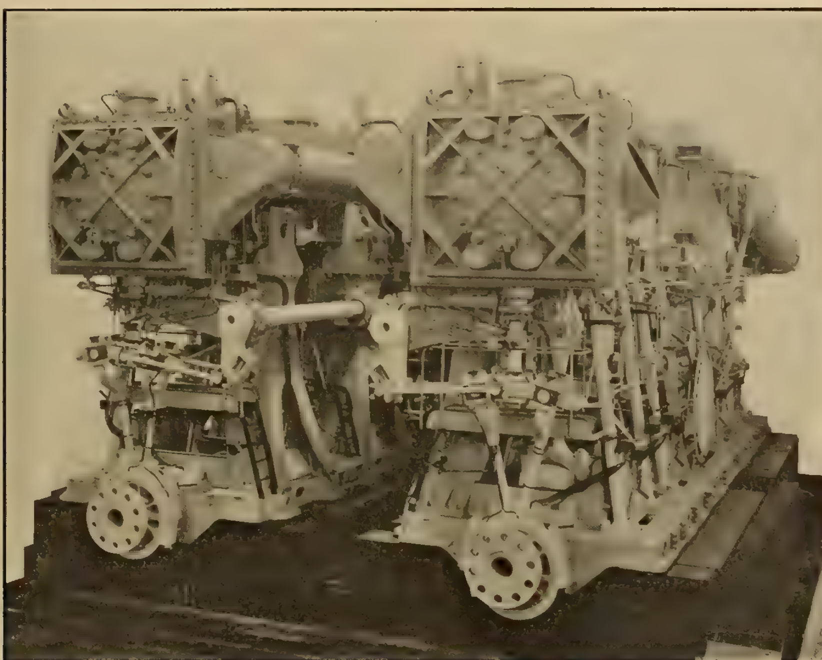
The engines of the *Africa* are two sets of four-cylinder, triple-expansion type, each having one high-pressure cylinder 38 inches diameter, one intermediate cylinder 60 inches diameter, and two low-pressure cylinders 67 inches diameter, with a common stroke of 48 inches. They are fitted with a system of forced lubrication, oil being supplied under pressure to the crank-pins, main bearings and eccentric sheaves by independent steam pumps. They are together capable of developing 18,000 horse-power when working at 120 revolutions per minute. Steam at 210 pounds pressure is supplied by eighteen water-tube boilers of the Babcock & Wilcox type and three boilers of the cylindrical return-tube type working under forced draught on the closed stokehole system.



ENGINES OF H. M. S. DOMINION. VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS

The *Caronia* is fitted with two sets of quadruple-expansion engines, each working on four cranks and having one high-pressure cylinder 39 inches diameter, one first intermediate cylinder 54½ inches diameter, one second intermediate cylinder 77 inches diameter and one low-pressure cylinder

110 inches diameter, with a common stroke of 66 inches. Steam at 210 pounds pressure is supplied by eight double-ended and five single-ended boilers of the cylindrical return-tube type, having a grate area of 1,300 square feet and a heating surface of 52,000 square feet. The boilers are arranged to work with closed ashpits and heated air on the Howden system, and are easily capable of supplying steam to the engines sufficient for maintaining 20,000 horse-power at sea.



ENGINES OF H. M. S. NATAL. VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS

The twin-screw steamer *Duke of Connaught* is a fast Channel steamer running for the Lancashire & Yorkshire and London & North-Western Railway's joint service between Fleetwood and Belfast, and is fitted with two sets of four-cylinder, triple-expansion engines, each having one high-pressure cylinder 23 inches diameter, one intermediate-pressure cylinder 34 inches diameter and two low-pressure cylinders 38½ inches diameter, with a common stroke of 33 inches. They are together capable of developing 5,700 horse-power when working at 165 revolutions per minute and propelling the ship at a speed of 20 knots. Steam is supplied by five single-ended boilers working on the closed-stokehole system of forced draught and having 320 square feet of grate and 10,400 square feet of heating surface.

The Fairfield Shipbuilding & Engineering Company, Ltd., have built the engines of the Canadian Pacific Railway Company steamers *Empress of Britain* and *Princess Charlotte.*

The engines of the *Empress of Britain* are of the quadruple-expansion type, balanced on the Yarrow-Schlick-Tweedy system. The cylinders are 36, 52, 75 and 108 inches diameter by 5 feet 9 inches stroke, and arranged in the following sequence, beginning at the forward end: high-pressure, second-intermediate, low-pressure and first-intermediate.

The two sets developed 18,500 horse-power on trial with a steam pressure of 220 pounds.

The regulating and throttle valves are worked by separate steam and hydraulic engines, the latter being controlled by an inertia governor on the main engine. The valve gear is of the Stephenson link-motion type, with slot levers for the separate adjustment of the cut-offs in the various cylinders, and fitted with a double-cylinder all-round reversing engine.

The high and first intermediate-pressure cylinders are fitted with balanced piston-valves, and the second-intermediate and low-pressure with double-ported flat valves and assistant cylinders. The shafting throughout is of fluid pressed steel, and the angles between the cranks are arranged to suit the system of balancing. The condensers are of cast iron, and form part of the structure of the engine.

There are no pumps worked from the main engine crossheads, the air, hotwell and bilge pumps being independent and driven by separate steam cylinders.

The *Princess Charlotte's* engines are of the triple-expansion type with four cylinders and four cranks, and designed to develop 6,600 indicated horse-power.

The cylinder diameters are: high-presure 24 inches, intermediate 38 inches, and two low-pressure each 43 inches, and the stroke 2 feet 9 inches.

The engines are balanced on the Yarrow-Schlick-Tweedy system, and special attention has been paid to the design, in order that the inertia forces may be taken up by the structure of the engines and not be transmitted to the tank top to set up vibration in the vessel. Owing to the requirements of the service, these engines are as light as possible consistent with economy of working. They are fitted with all-round reversing gear, Aspinall's governors, automatic drain-traps on the receivers to prevent loss due to the re-evaporation of condensed steam, assistant cylinders on the slide valves and metallic packing in all the piston rod and valve spindle glands.

The crankshafts are made from solid forgings, and are in two lengths for each engine.

The propellers, which are of bronze, turn outwards, and the open sides of the engines with the forged steel columns are towards the sides of the vessel, giving free access for attendance, and leaving the starting handles and gear towards the centre line free to enable one man to control, without obstruction, both sets at once.

The condensers are built of steel plates and placed in the wings of the engine room. The air, circulating and other pumps are also independent of the main engines.

The Vulcan Company, of Stettin, have contributed six examples of high-class engineering: The gunboat *Eber,* of 1,300 indicated horse-power, and the cruiser *Hamburg,* of 10,000 indicated horse-power, both built in 1903; the battleship *Preussen,* of 16,000 indicated horse-power, built in 1904; a torpedo cruiser for the Russian Navy, 500 tons displacement, speed 27 knots and 6,800 indicated horse-power, built in 1905; a torpedo cruiser for the Greek Navy, displacement 350 tons, speed 30¾ knots and 6,800 indicated horse-power; and finally the four-cylinder, quadruple-expansion engines of the *Kaiserin Auguste Victoria* for the Hamburg-Amerika Line, 17,500 indicated horse-power, and balanced on the Schlick system. This latter vessel was built in 1906.

Apart from the introduction of turbines there is no doubt that the advent of the water-tube boiler is largely responsible for the extraordinary advance made in recent years in naval engineering.

In the earlier stages the water-tube boiler was fitted in torpedo boats, but in 1893 the torpedo gunboat *Speedy* was fitted with Thornycroft water-tube boilers and showed an advantage over the sister vessel fitted with locomotive boilers.

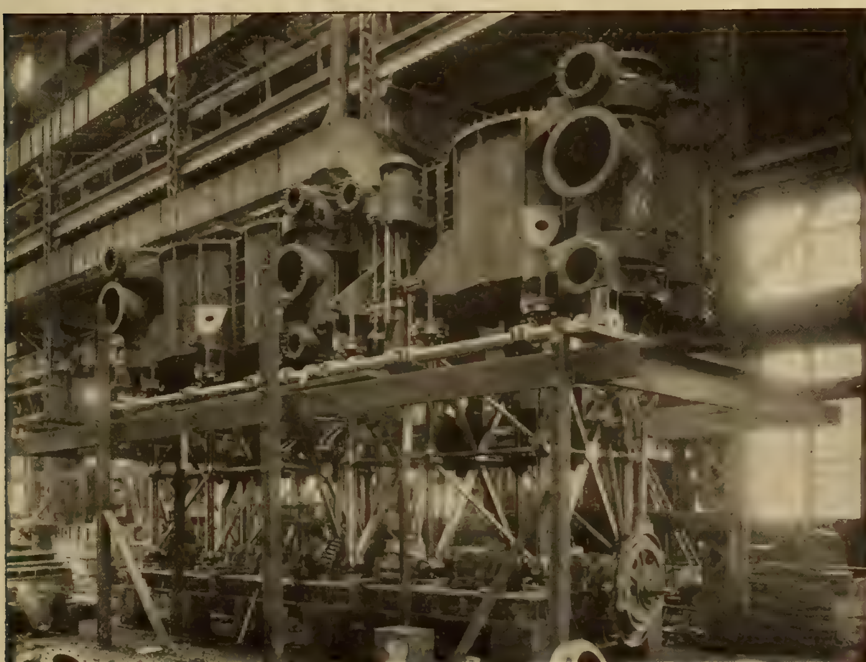
These torpedo gunboats were followed by a new class of vessel called torpedo-boat destroyers. Messrs. Yarrow & Co. fitted their usual locomotive boilers in the destroyer *Havock*, but in the sister ship *Hornet* they fitted their water-tube boilers and obtained an extra knot in speed. Messrs. Thornycroft fitted their water-tube boilers in the *Daring* and *Decoy*, and Messrs. Laird Brothers fitted Normand boilers in the *Ferret* and *Lynx*. These water-tube boiler boats all obtained the required speed of 27 knots satisfactorily.

The next batch of destroyers had various makes of boilers, and also locomotive boilers in two vessels built on the Clyde.

These locomotive boilers were, however, removed and Reed water-tube boilers fitted before the vessels were delivered, so that it may fairly be said that, after the first destroyer *Havock*, all were fitted with water-tube boilers, and even the *Havock* was at a later date fitted with Yarrow water-tube boilers.

The more recent vessels of this class were fitted with Yarrow, Thornycroft, Reed, Normand and White-Foster water-tube boilers, all of the small tube or express type, and the suitability of this class of boiler was proved beyond all doubt.

With regard to the water-tube boiler question in larger vessels, the torpedo gunboat *Sharpshooter* was, in 1894, fitted with Belleville boilers, and after extended experiments in this vessel and consideration of the comparatively extensive adoption of Belleville boilers in French vessels it was decided to adopt this type of boiler in the two cruisers *Powerful* and *Terrible*, then being designed.



ENGINES OF THE SOUTH CAROLINA. WM. CRAMP & SON, PHILADELPHIA

When it is remembered that these vessels had machinery of 25,000 horse-power, practically double that of any existing British warships and nearly ten times the power developed in the *Sharpshooter* with the experimental boilers, it must be admitted

that it showed very great confidence and courage on the part of the Admiralty Engineering Department to make such a large experiment.

As a result of the experience gained the Belleville boiler was adopted as the standard boiler for battleships and large cruisers. The boiler pressure adopted was 300 pounds per square inch, with about 250 pounds at the engines. With this increase of working pressure from 150 pounds to 250 pounds and the increased revolutions previously referred to, the adoption of the water-tube boiler was accompanied by increased power, being provided in practically all war vessels with a corresponding increase in speed.

In third-class cruisers the small-tube express boiler was used, of the Thornycroft, the Reed, the Normand and the Blechynden types.

In the last four third-class cruisers of 1903-4 Yarrow, Reed and "Laird-Normand" boilers were fitted.

While the Belleville boiler continued to be fitted as the standard boiler the Admiralty were making experiments with other types, amongst which were the Niclausse, Yarrow large-tube, the Dürr and the Babcock & Wilcox boilers. Troubles, however, with some of the earlier Belleville boilers led to the formation of the Admiralty Boiler Committee in 1900, and the boiler question became one of national interest.

The reports of this committee have been published and form a very interesting and valuable collection of information. On their recommendation the fitting of Belleville boilers was discontinued and further experiments carried out in the *Medea* and *Medusa* with Yarrow large-tube boilers and Dürr boilers, also in vessels fitted with other types. Various combinations of cylindrical and water-tube boilers were fitted in new cruisers; but the boiler question for large ships has resolved itself for the present into fitting homogeneous installations of water-tube boilers, either of Yarrow large-tube boilers or Babcock & Wilcox marine boilers.

Referring again to the Belleville boiler, it may be said that the earlier boilers suffered from the necessity of fitting welded tubes and from the experimental nature of their manufacture not having fully brought out the importance of the very best workmanship possible.

The steel tube industry has since developed rapidly, and the later vessels had seamless steel tubes and no doubt more accurate workmanship; be that as it may, a large number of these boilers are said to have done extremely well. At the same time, the Belleville boiler is one of the most complicated and most difficult to manufacture and repair, and better results may reasonably be expected from the types eventually adopted.

In the merchant service comparatively little progress has been made in fitting British-built ships with water-tube boilers. A considerable number of Babcock & Wilcox boilers have, however, been fitted in American-built ships.

It may truly be said that the ordinary cylindrical return-tube boiler of the single and double-ended types still holds its own as the standard steam producer in the merchant service.

Although the ordinary tramp steamer is, as a rule, fitted for natural draught only, it has become more and more the practice in the larger and more powerful vessels to use heated air-supply on the well-known Howden and similar systems.

With the higher pressures and consequently thicker plates now adopted, it has been clearly demonstrated that the hot-air system is more conducive to less wear and tear and to longer lifetime than the cold-air system, and at the same time it is accompanied by a reduction in coal consumption. The fitting of superheaters has in recent years engaged a certain amount of attention, but it cannot be said that they are adopted to any great extent.

The use of oil fuel in the merchant service continues to be limited to oil-tank steamers, but in the navy its use has extended to a very great extent as a consequence of the successful results obtained in the Admiralty experiments. The majority of battleships and cruisers recently built are fitted for the use of oil fuel, as well as coal; but all the torpedo boats and torpedo-boat destroyers recently built for the British Navy have been fitted specially for burning oil, and this system, combined with the turbines, has been responsible for the extraordinarily high speeds obtained recently in the 33-knot destroyers, as, for instance, the *Tartar,* a vessel 270 feet long, which is reported to have maintained a speed of 35.36 knots for six hours.

With regard to the adoption of Yarrow boilers as one of the standard boilers for large British ships, it may be noted that in the Dutch battleships of the *Koningin Regentes* class laid down in 1898 this type of boiler was fitted, and this fact was before the Boiler Committee. This boiler has been largely adopted in several navies; illustrations are given of the boilers for the Chilean battleships *Constitution* and *Libertad* (now the British ships *Swiftsure* and *Triumph*); the designed indicated horse-power per vessel was 12,500 and the number of boilers twelve.

The total heating surface of these boilers is 37,524 square feet, and the total grate surface is 664 square feet. The tubes are 1¾ inches outside diameter and about 6 feet 9¼ inches long. The weight of one boiler complete is 34½ tons, including water. The working pressure is 280 pounds per square inch.

Extensive evaporative trials were carried out on shore with one boiler on a twenty-four hours' trial with 53 square feet of grate; the evaporation per hour was 15,700 pounds, or 9.96 pounds per pound of coal from and at 212 degrees Fahr.

With grate area further reduced to 40 square feet the rate of evaporation was 16,680 pounds per hour, or 10.57 pounds of water per pound of coal from and at 212 degrees Fahr.

On the six-hours' full-power trial an average of 14,000 horse-power was maintained, with a consumption of 1.73 pounds of coal per indicated horse-power per hour.

The Babcock & Wilcox marine boiler, which has been adopted as one of the alternative types in the British Navy, has comparatively large tubes. The type is well known and has been very extensively used in American vessels, both mercantile and naval. The experience in British war vessels has shown it to be a very reliable type, but the weight is greater than the alternative Yarrow type. This type of boiler is fitted in more than twenty British warships, including such vessels as the *Indomitable* and the *Dreadnought.*

The Thornycroft boiler in its older form is well known, but in recent years the shape of the tube has been modified.

The Laird-Normand boiler is a development of the Normand boiler first fitted in this country in the destroyer *Ferret* by Laird Bros. This has been extensively used, particularly in destroyer work and in third-class cruisers, as already referred to. Messrs. Laird Bros. have had very successful results with this in these 33-knot destroyers.

The Reed boiler was first used in the 27-knot destroyer *Janus,* and has been fitted in twenty-seven of the destroyers built by Palmers Company, Jarrow; also in torpedo gunboats and third-class cruisers and in destroyers built by other firms. It is of the bent-tube variety, and the tubes are so fitted that they can be readily removed and replaced without injury.

In evaporative trials on shore with one of these boilers an evaporation of 11.6 pounds of water per pound of coal from and at 212 degrees Fahr. has been obtained.

On a trial of one of the large type for torpedo gunboats having 3,424

square feet of heating surface and 71.75 square feet of grate surface, the evaporation was at the rate of 47,200 pounds per hour from and at 212 degrees Fahr.

The White-Forster boiler is fitted in a large number of fast vessels of the torpedo boat and torpedo-boat destroyer type, including such vessels as the *Mohawk*, which attained a speed of 34.24 knots on her trials.

It is of the bent-tube type, but all the tubes are to the same curvature and can be drawn through the manholes of top chamber.

There is no doubt that the most radical stage of development in modern marine engineering has been the adoption of the steam turbine. This had been used on shore for several years previously, but it was not until 1894 that the Hon. C. A. Parsons put it into practical use on board the historic *Turbinia* as a means of propulsion.

This little vessel, the first fitted with steam turbines, was 100 feet in length and 44½ tons displacement. She was at first fitted with a single screw shaft, and obtained a speed of 19¾ knots. Two years later, in 1896, after fitting three shafts with a turbine on each, a mean speed of 32.76 knots was obtained. Afterwards in the Solent a speed of 34 knots was reported to have been attained—truly at that time a remarkable speed for such a diminutive vessel.

PARSONS STEAM TURBINES FOR U. S. TORPEDO BOATS NO. 17 AND 18. WM. CRAMP & SON

The next step was the fitting of the destroyer *Viper* for the British Government with Parsons turbines in 1898, and this was the first war vessel so fitted. This was a considerable advance on the *Turbinia*, the vessel being 210 feet long and 370 tons displacement. The mean speed on an hour's run was 36.581 knots, with an estimated horse-power of 11,500.

The first passenger vessel to be propelled by steam turbines was the

King Edward, built in 1901 by Messrs. Denny Brothers, Dumbarton, and engined by the Parsons Marine Steam Turbine Company. She was 250 feet long, with a speed of 20.43 knots.

These vessels were quickly followed by others for passenger service on the Clyde and for Channel service, and as yachts; but the three vessels above mentioned, the *Turbinia, Viper* and *King Edward,* will always stand out as marking important periods in the introduction of the marine steam turbine.

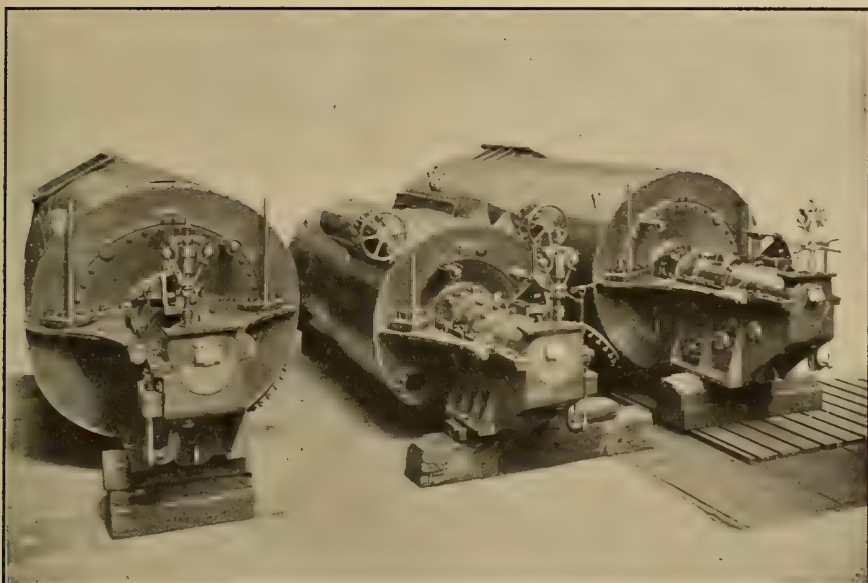
Passing over the intervening vessels, we next refer to the cruiser *Amethyst,* which is closely associated with the most decisive step taken in naval engineering.

This was the first cruiser fitted with turbines, and the experiment was of the utmost importance, inasmuch as this was one of four similar-sized cruisers, the other three being fitted with reciprocating engines. The four vessels referred to are the *Amethyst,* constructed by Sir W. G. Armstrong, Whitworth & Co., and fitted with turbines by the Parsons Marine Steam Turbine Company and boilers of the modified Yarrow type; the *Diamond* and *Topaze,* built and engined by Cammell, Laird & Co., Ltd., with Laird-Normand boilers in the *Topaze* and Yarrow boilers in the *Diamond;* and the *Sapphire,* built and engined by Palmers S. & I. Company, Ltd., and fitted with Reed boilers.

These vessels are all 360 feet long, 40 feet beam and 3,000 tons displacement on 14 feet 6 inches draught. The designed power was 9,800, and the speed 21¾ knots. The reciprocating engines drive twin screws, and were designed for 250 revolutions per minute. They have four cylinders to each set, the high-pressure cylinder being 24¼ inches, the intermediate 38½ inches and the two low-pressure 42¼ inches diameter, all with a stroke of 24 inches.

The boilers are ten in number and 300 pounds per square inch working pressure, of the small-tube variety and of the types already named.

The turbines of the *Amethyst* are

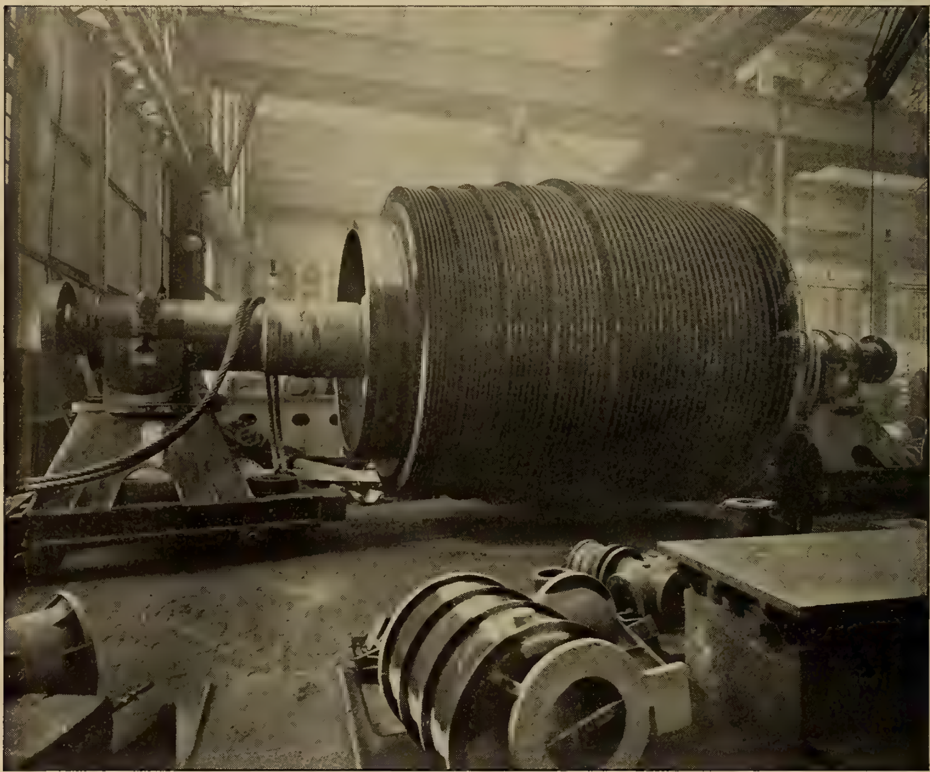


GENERAL ARRANGEMENT OF A SET OF TURBINE MACHINERY

arranged on three shafts. The main high-pressure turbine drives the centre shaft, whilst a low-pressure turbine is placed on each wing shaft. Cruising and astern turbines are also on the wing shafts.

Extensive comparative trials were made, of which very complete details appeared in *Engineering*. These trials showed very emphatically that attained a speed of 22.34 knots with 10,200 indicated horse-power and a total water consumption for main and auxiliary engines of 226,440 pounds per hour.

The *Amethyst's* speed was 23.63 knots, with an estimated power of 14,000 horse-power and a total water consumption of 190,525 pounds per hour.



LOW-PRESSURE TURBINE ROTOR OF LUSITANIA

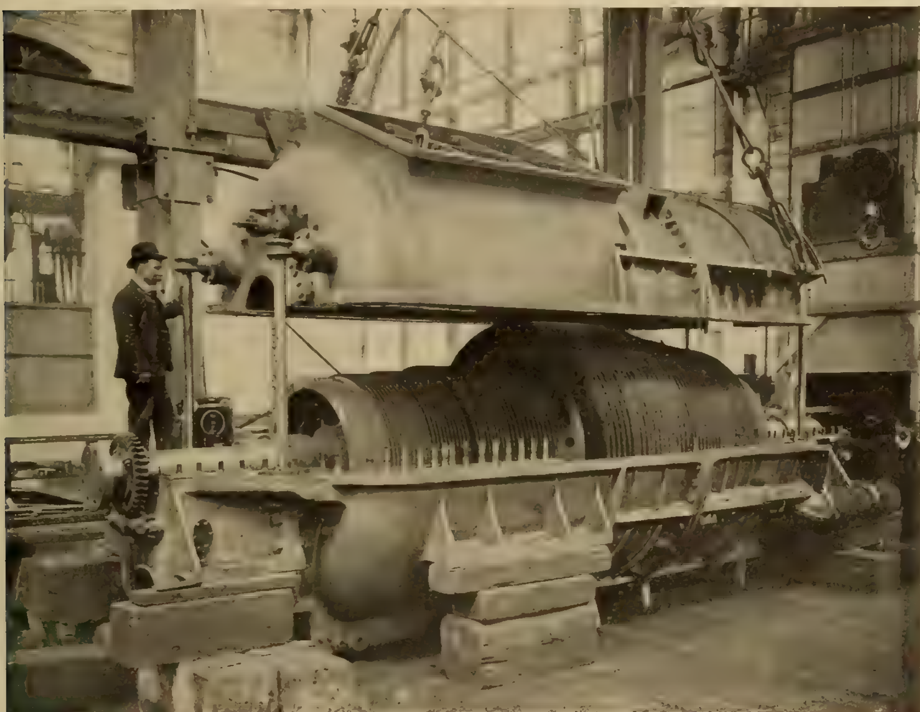
the amount of steam used by the turbines was much less than used by the reciprocating engines at all speeds above about 15 knots; but since these trials were completed the auxiliary exhaust steam has been taken into the main turbines, resulting, as stated in a paper by Mr. R. J. Walker (of Parsons Company), in bringing the steam consumption below that of the reciprocating engines, even so far down as 10 knots speed.

The *Sapphire* on full-power trial

This shows that with 1.29 knots more speed about 16 per cent. less water was used. On the eight hours' trials in the region of 20 knots the *Sapphire* showed 20.68 knots, 7,281 indicated horse-power and 144,160 pounds of water per hour, while the *Amethyst* showed 20.6 knots and an estimated power of 7,280, with a water consumption of 100,606 pounds per hour, or over 29 per cent. less water at practically the same speeds.

These results were so decisively in

favour of the turbines that the battleship *Dreadnought*, laid down in 1905, was fitted with this method of propulsion. The details of the trials as published show that she obtained a speed of 21.25 knots, with a water consumption for main and auxiliary engines of 15.56 pounds per horse-power, with the main engines giving 24,712 horse-power, as measured by torsionmeter.



TURBINE ENGINES FOR WARSHIPS, UNDER CONSTRUCTION AT THE WORKS OF MESSRS. VICKERS, SONS & MAXIM, BARROW-IN-FURNESS

These turbines were the largest fitted to any war vessel, and the results appear to have been so satisfactory as to be responsible for the decision of the British Admiralty to fit all new war vessels with turbines. The fact, at any rate, remains that no reciprocating engines have been ordered since these trials, and all British war vessels now building are turbine-propelled.

Thus in the short period of about six years from the *Viper* to the *Dreadnought* the turbine has made a complete conquest of British naval propulsion.

Whilst the maximum power put into war vessels in reciprocating engines has in this country been 30,000, as in the *Drake* class, and in France 36,000, as in the *Ernest Renan* class, we have now several cruisers of the *Indomitable* class with 41,000 horse-power in turbines. Japan has gone one better, and is providing 44,000 horse-power in turbines in her large armoured cruiser, while Germany has laid down a cruiser with 50,000 horse-power in Parsons turbines.

The United States, in the battleship *Delaware*, is, according to Laird Clowes, fitting Parsons turbines of 25,000 horse-power, and in the *North Dakota* the same power in

Curtis turbines, and is also carrying out an interesting experiment by fitting three similar scout cruisers with three methods of propulsion.

The *Birmingham* is fitted with reciprocating engines, the *Salem* with Curtis turbines and the *Chester* with Parsons turbines. These vessels are 420 feet long, 46 feet 8 inches beam, 16 feet 9½ inches draught, with 3,750 tons displacement. They were designed for 16,000 horse-power and 24 knots. They have twelve boilers of the express type.

When the trials have all been completed and compared they should form a valuable addition to the turbine data. In the meantime, it may be noted that the *Chester* is said to have steamed at 26.52 knots, the *Salem* at 25.94 and the *Birmingham* at 24.3 knots, showing the superiority of the turbine over the reciprocating engine.

Whilst this development was taking place in propulsion of war vessels a rapid advance was being made in the mercantile marine.

The first step has already been referred to as the *King Edward* in 1901..

In 1904 the Allan Line, in building their *Virginian* and *Victorian*, showed the growing confidence in turbine propulsion. These vessels were 520 feet long and had turbines of about 12,000 horse-power, and were the first turbine vessels of large size for Atlantic work. Their speed is stated as 19.11 knots and 18.75 knots, respectively.

Further light has been thrown on the relative performances of turbine and reciprocating engines for propulsion by the building and trial of four similar vessels for the Midland Railway Company. Two of these vessels, the *Antrim* and the *Donegal*, were fitted with reciprocating engines, and two, the *Londonderry* and the *Manxman*, with Parsons turbines.

The vessels are 300 feet long. In the Transactions of the Institution of Naval Architects many details are given, and form a means of comparison between the advantages of turbines and reciprocating engines.

The reciprocating engines were for twin screws, and had four cylinders to each set, high-pressure 23 inches, intermediate pressure 36 inches, two low-pressure 42 inches, stroke 30 inches.

The turbine steamers have three shafts, with one propeller on each. The high-pressure turbine is on the centre shaft and a low-pressure turbine on each wing shaft.

On the official trials, with 80 per cent. of the boiler power in use, the turbine steamer *Londonderry* obtained 21.6 knots, and the *Antrim*, with reciprocating engines, 20.6 knots, showing a gain of 1 knot. When driven at full power with all boilers in use the *Londonderry's* speed was 22.36 knots and the *Manxman's* 23.12 knots, while the *Antrim's* was 21.86 knots, the *Londonderry* showing a gain of 0.5 knot and the *Manxman* 1.26 knots.

The trial results further show that, as regards steam consumption, the turbine is more economical than the reciprocating engine for speeds from 14 to 20 knots, and that at the service speed of from 19 to 20 knots this economy is represented by about 11 per cent.

The decision of the Cunard Company in 1904 to build the *Caronia* with reciprocating engines and the *Carmania* with turbines afforded a very decisive means of comparison in large vessels, for these were 650 feet long between perpendiculars and about 21,000 horse-power, altogether a very great advance on the recent important step by the Allan Line.

Both vessels were built and engined by John Brown & Co., Ltd., and have been described in *Engineering*.

The *Caronia* was fitted with twin screws driven by quadruple-expansion engines, which have been described and illustrated in an earlier part of this article. On trial, the speed attained was 19.62 knots with 21,870 horse-power.

The *Carmania* was provided with Parsons steam turbines driving three shafts. The high-pressure turbine is placed on the centre shaft, while one low-pressure and an astern are placed on each wing shaft.

The boilers are similar to those of the *Caronia,* except that the pressure is 195 pounds per square inch.

On trial, the *Carmania* attained a speed of 20.19 knots, or ½ knot better than the *Caronia,* which, together with the general performance, demonstrated once more the suitability of the turbine as a means of propulsion in high-speed vessels.

Following these two vessels, we have what at present appears to be the crowning effort in the development of the modern marine engine.

When the Cunard Company agreed with the British Government to build two fast Atlantic liners it was a source of general satisfaction to the British nat.on, particularly to the shipbuilding and engineering fraternity, as it meant that the blue riband of the Atlantic would come again into healthy competition, and that there was every probability of it coming again into British hands.

For many years, in fact since the advent of the *Kaiser Wilhelm der Grosse,* this had been held successfully by German lines.

The two new vessels, the *Lusitania* and the *Mauretania,* were to be capable of maintaining an ocean speed of 24½ knots, or about one knot more than existing vessels.

They are 760 feet long between perpendiculars and 38,000 tons displacement. As the designed power was 68,000 horse-power, or fully 50 per cent. greater than the most powerful yet built, the problem was unprecedented.

Particulars of the various steps leading up to the adoption of Parsons turbines and a large amount of later information have already appeared in *Engineering,* and show that every possible precaution was adopted to ensure success. At the same time, the magnitude of the step must forever remain as testimony to the courage of the owners and the skill and resource of the builders and the Hon. C. A. Parsons.

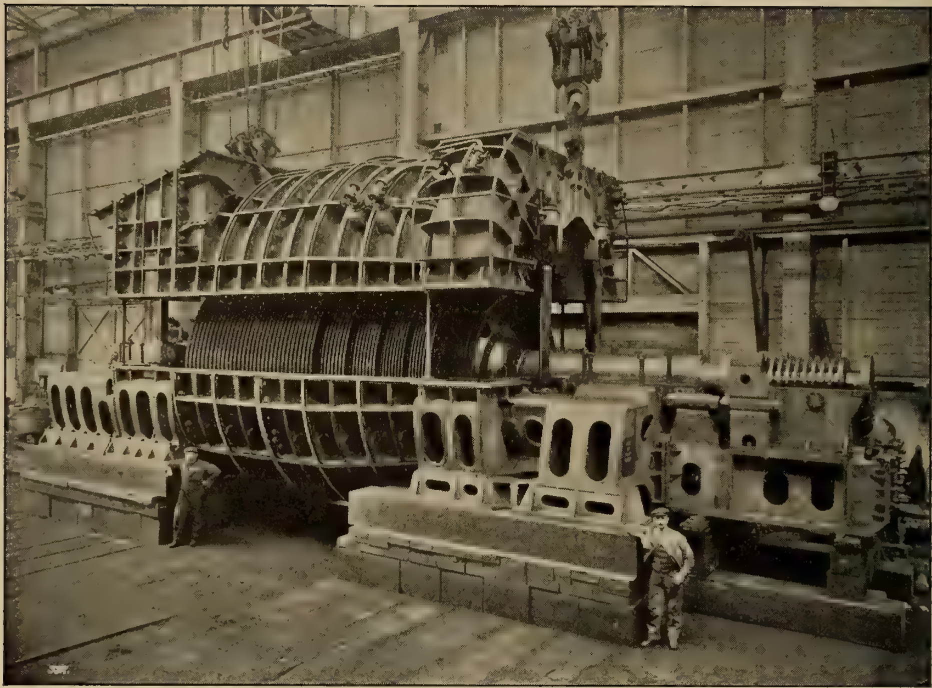
Without in the least underrating the importance of the step made in the building of the hulls, it is fully admitted that in the propelling machinery we have the centre of interest, as the problems to be faced were so very far in advance of anything that had been done.

The turbines were required to develop more than three times the power of the *Carmania* or the *Dreadnought,* and even these examples were, to a considerable extent, experimental.

The building of both hull and machinery for the *Lusitania* was entrusted to John Brown & Co., Ltd., Clydebank, while the hull of the *Mauretania* was built by Swan, Hunter, Wigham Richardson & Co., Ltd., on the Tyne, the machinery being constructed by the Wallsend Slipway & Engineering Co., Ltd.

Although the main features of the machinery are the same for both vessels, it is evident, from the very complete description in *Engineering* and from an inspection of the actual machinery, that the two firms have worked to a considerable extent on independent lines; and it is well, from an engineering point of view, that this is the case, as the effect the differences have on the end in view forms very interesting points of experiment. The power is transmitted through four shafts, and the turbines are placed in three compartments. A high-pressure turbine is placed in each wing compartment, and on each of the two centre shafts there is a low-pressure and an astern turbine. The astern turbines are independent and not incorporated with the low-pressure, as was the case with the *Carmania.*

In the *Mauretania* the high-pressure drums are 8 feet diameter and about 10 feet over the blades. The astern drums are 8 feet 8 inches diameter and about 10 feet over the



LOW-PRESSURE TURBINE AND ROTOR OF THE MAURETANIA, SHOWING THE TOP HALF OF THE CASING LIFTED

blades. The low-pressure drums are 11 feet 8 inches diameter and about 15 feet 4 inches over the blades, and it appears that one high-pressure rotor complete weighs 72 tons, one low-pressure rotor 126 tons and one astern rotor about 60 tons.

The figures are cited to give some idea of the extraordinary size of the turbines and the problem that had to be faced in their manufacture. One important difference between the turbines of the two ships is in the rotor wheels. The *Lusitania's* are steel castings, whereas the *Mauretania's* are of forged steel and machined all over. From a purely engineering point of view, the forgings would appear to be the ideal method of construction, on account of their homogeneity and reliability of material and absolute balance, due to machining. At the same time, the builders of the *Lusitania* have succeeded in obtaining eminently satisfactory castings, and with the care they have taken appear to have arrived at a very similar efficiency of balancing.

The steam-generating plant in the two vessels is practically the same. There are twenty-three double-ended and two single-ended boilers, working at 195 pounds pressure. The total heating surface in the *Mauretania* is about 159,000 square feet and the total grate surface about 4,060 square feet. The *Lusitania's* double-ended boilers are given as 17 feet 6 inches diameter and 22 feet long, and the single-ended boilers the same diameter and 11 feet 4 inches long; total heating surface 158,352 square feet and total grate surface 4,048 square feet. They are placed in four water-tight compartments and fitted with Howden's system of forced draught.

The trials and general performances of these vessels and their machinery have been a great success, and from particulars given by Mr. Bell before the Institute of Naval Architects the *Lusitania* on her full-

power trial made a speed of 25.4 knots with a shaft horse-power of 68,850. In the discussion on this paper, Mr. Laing stated that the *Mauretania's* speed under the same conditions was 26.04 knots. On the voyage these vessels have done splendidly, the *Lusitania* having averaged 24.83 knots and the *Mauretania* 24.84 knots, with a prospect of doing still better. These speeds, however, are considerably in excess of the best average of the German vessels.

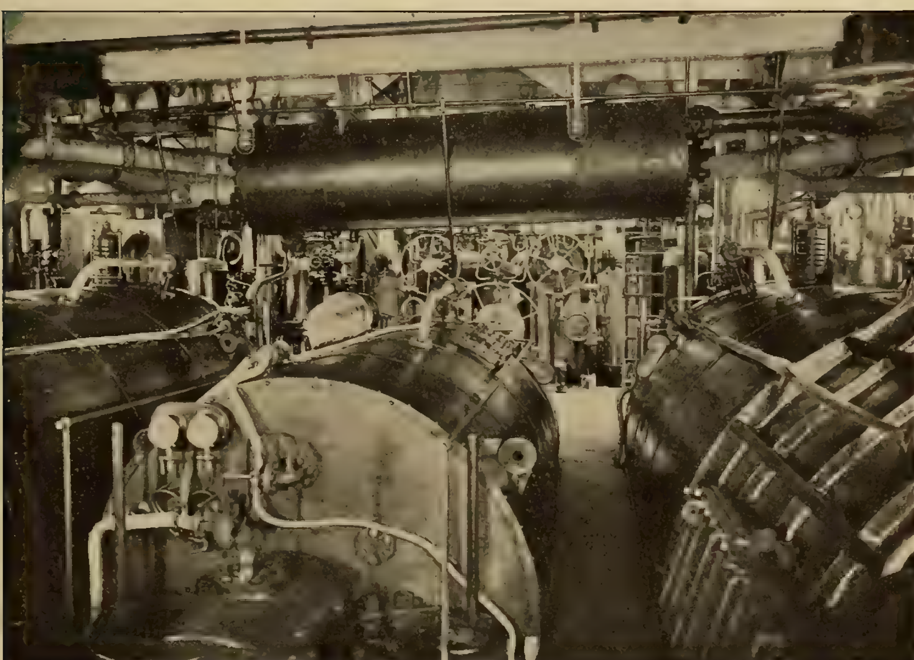
The amount of steam used in this large installation is of special interest, and the trials of the *Lusitania* show that the total consumption was 14.46 pounds per hour, whilst for the turbines alone this was 12.77 pounds per hour per horse-power.

In the case of the Boiler Committee's trials of the *Saxonia* the main engines (reciprocating) were found to use 13.47 pounds per horse-power per hour, which shows that the steam turbine, in what may be called its early stages of application, is more economical than the reciprocating engine in a stage of development embodying the experience of long years of progress.

TABLE SHOWING DEVELOPMENT OF THE STEAM TURBINE IN MARINE AND MERCHANT VESSELS.

Year.	Name.	Length, Feet.	Horse-Power.
	WAR VESSELS.		
1894	*Turbinia*	100	2,100
1899	*Viper* (destroyer)	210	11,500
1904	*Amethyst* (cruiser)	360	14,000
1906	*Dreadnought* (battleship)	490	24,500
1907	*Indomitable* (cruiser)	530	41,000
Building	*Haki*, Japan (cruiser)	537	44,000
Building	"*F*," Germany (cruiser)	560	50,000
	MERCHANT VESSELS.		
1894	*Turbinia*	100	2,100
1901	*King Edward*	250	3,500
1904	*Virginian and Victorian*	520	12,000
1904	*Carmania*	650	21,000
1907	*Lusitania* / *Mauretania*	760	68,000

Other directions in which marine engineering is developing may be noted as the combination of the turbine with reciprocating engines, as dealt with in a paper before the Institute of Naval Architects by the Hon. C. A. Parsons and R. J. Walker, Esq., and the result of the trials of the combination, under construction at Messrs. Harland &



VIEW IN A TURBINE ENGINE ROOM, SHOWING TURBINES AND STARTING PLATFORM, ISLE OF MAN STEAMER VIKING

Wolff's, will be looked for with interest, as it seems to open the way for further economy in the intermediate class of vessel.

The internal-combustion engine for marine propulsion has made rapid strides in the smaller class of boat fitted with petrol motors, and the high speeds attained in these wonderful little craft no doubt foreshadow unheard-of results in large vessels, provided a thoroughly satisfactory reversible engine using oils of a high flash point is developed or the practical difficulties connected with gas-producer combinations are overcome. Many experiments are in the field, and it would be extremely rash to suggest that none of these will be successful; but it is fairly safe to say that the steam engine in its new garb of the steam turbine combined with oil fuel will not be displaced for some years to come.

The subject of this article is extremely wide and comprehensive, and one that cannot be done justice to in the limits available; hence nothing more than treating it in outline has been attempted.

OIL BURNING ON BOARD SHIP

By Andrew Laing, M. I. N. A.

THE engineer of to-day has of necessity to regard all subjects from the commercial, as well as the purely mechanical, point of view, and fortunate is he who has foreseen this contingency and has added to his period of apprenticeship in the shops a sufficiently long training in the counting house to cultivate the mental attitude required for tackling business problems. It is not altogether a question of supervising costs. That is too closely allied to mechanics to be ignored by the capable apprentice. There are other considerations which present themselves in the determination of managerial policy. The correct reading of the future prospects of markets makes or mars the success of a contract where material has to be bought. Potentialities of new inventions dependent upon commercial considerations can only be rightly weighed by the engineer who has developed those qualities which are embraced in the characteristics of the "man of affairs." One of the most interesting examples is to be found in the question of the use of oil fuel, and no excuse need therefore be made for these reflections, or for considering the subject from the commercial as well as the mechanical standpoint.

It may be accepted as a truism that where there is certainty of commercial success, mechanical difficulties will be overcome. The measure of the ingenuity developed is in direct proportion to the probabilities of monetary reward. Thus the problems of successfully using crude oil as a fuel for steam production have been satisfactorily solved, as shall presently be explained; the extent of application of the system is dependent upon commercial questions, and primarily upon the adequacy of sources of supply, the distribution of the oil, and the selling price. Are these likely to become more favourable with increased demand?

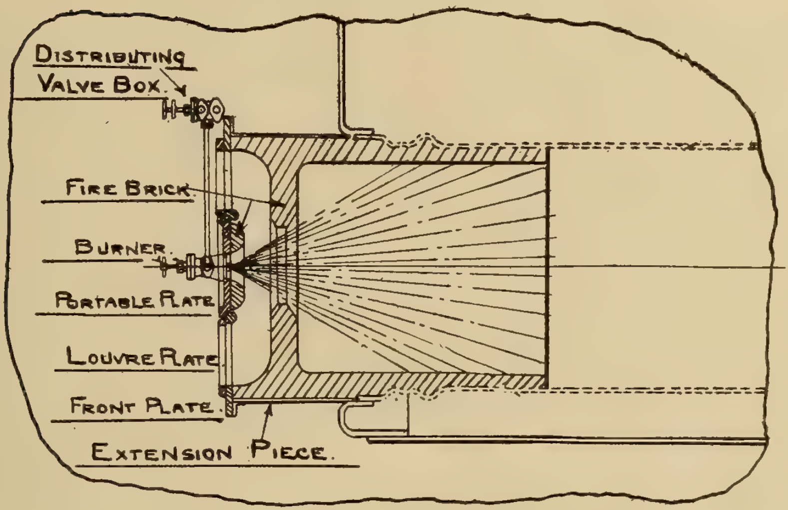
The total production of crude petroleum from all sources last year was within a small fraction of 9,000 million gallons, about 35 million tons. On the other hand, the world's output of coal was nearly 1,110 million tons. These figures show how far the supply of oil falls short of meeting the fuel requirements were it adopted wherever possible. The imports to the United Kingdom of petroleum in all forms are now about 300 million gallons per annum, equal in value to nearly five and three-quarter million sterling; whereas the consumption of coal, taking production minus shipments, is over 190 million tons. In neither instance is the fuel used in British ships taking coal or oil at foreign ports included. So far, the demand of oil has been in excess of the supply; the motor car absorbing a rapidly increasing proportion. Thus in 1905 the quantity of petrol imported was 18½ million gallons, and in 1907 more than 33 million gallons. As a rule demand creates supply, and much is being done to meet the wants of oil, whether for internal combustion engines or steam generation

The principal fields of oil suitable for use as fuel for steam-raising purposes are the Californian, Texas, Russian and Borneo wells. Practically all of the Texas oil, and a large proportion of the Californian oil, is available as fuel, and with

these copious fields the price need not be prohibitive of its use in successful competition with coal in those parts of the world where liquid fuel can be obtained easily and without transport over long distances. Other sources are being developed. Regarding these, most importance attaches to the possibility of finding liquid fuel in the British colonies, because there must ever be some anxiety in the event of any dependence on foreign supplies of oil for warships using it as fuel. It is true, capacious tanks for storing oil fuel have been or are being constructed by the Admiralty at many bases, but certainty of supply can only rest upon imperial sources. The principal field within the British Empire is in India, or rather Burmah. In ten years the supply has increased from 19 to 140 million gallons—almost all from Burmah. There are also promising developments in Canada; but Great Britain is yet some way from being independent of foreign purveyors.

The distribution of supply, or rather the facility with which oil can be obtained on ocean routes, is another important element in its successful application. There are depots for the storage of liquid fuel at Thames Haven and Central Wharves, London, and at Manchester, Barrow, and Bristol harbours. These installations are, of course, independent of the extensive storage which has been erected by the Admiralty for their own requirements. Extensive stocks of liquid fuel are also kept at the following places on the route to the Far East: Suez, Colombo, Calcutta, Bombay, Madras, Penang, Singapore, Batavia, Hong-Kong, Bangkok, Sourabaya, Shanghai and Port Arthur. There are stores also at certain Japanese and South American ports. Supplies of liquid fuel can also be obtained at the producing centres in the Black Sea, at Texas, at Balikpappan, East Borneo, at several Californian ports in the neighbourhood of San Francisco and at Constantza, Roumania.

The question of the use of oil for boilers in ships is largely one of pounds, shillings and pence, excepting in warships. Strategical and tactical considerations must predominate in this as in all matters associated with the fighting ship. This embraces, of course, the weight factor, where the advantage is with oil, and to this reference will be made later. But an additional point favourable to the naval service is the facility with which oil can be dealt with. In recharging a ship with fuel, the gain in time is enormous, as contrasted with the refilling of coal bunkers. In getting coal from distant bunkers at the end of or during a running fight, much labour is required when all hands may be needed for serving the guns. Even then the speed of a ship may be checked through insufficient supply. At such times, too, there is always danger of fires being choked with clinker, whereas with oil no such serious disadvantage can arise. In small craft, such as destroyers, the saving in weight makes it possible to realize speeds far in advance of those possible with coal. Thus, 30-knot destroyers using coal for raising steam for reciprocating engines require 25 tons of coal for 4-hours' run at 6,000 indicated horse-power, equal to 120 nautical miles at full speed. The displacement was 335 tons, so that the consumption of coal per 100 ton-mile was 139 pounds. It is not necessary to enforce the great increase of power required for 34 knots in the later British destroyers, especially as the vessels are larger and more seaworthy, being of 890 tons displacement. These vessels steamed at a speed of more than 34 knots for 6 hours, or for 207 nautical miles for 68¼ tons of fuel. Notwithstanding the greater power, nearly three times that of the 30-knot boats, the oil consumption was only 83 pounds per 100 ton-mile. Part of the credit for this result is no doubt due to the higher efficiency of the Parsons steam turbine at high speeds,



ATTACHMENT OF OIL BURNER TO AN INTERNAL FURNACE

but without oil fuel this speed result could not be achieved. The gain is applicable in practically the same degree to large fighting ships.

In the merchant service the main consideration is financial, which is concerned, not only with the relative calorific value for a given expenditure, but with the less weight and easier stowage of oil fuel, and consequent greater passenger and cargo capacity within a ship of given dimensions, and the greater facility of handling and resultant reduction in staff.

Experience goes to show that one ton of liquid fuel is of the same value as 1½ tons of average coal as a steam-raising agent. This ratio may be taken as well within the mark, as some authorities state that 1 ton of oil is equivalent to 1¾ tons of coal.

The volume of 1 ton of oil runs out at about 38 cubic feet, whereas 44 cubic feet of bunker space must be allowed for each ton of coal. From the above data it will be seen that for any given vessel, if oil fuel is adopted, the capacity of the bunkers can be reduced nearly 45 per cent., as compared with what they would require to be if burning coal; since not only is the weight of fuel to be carried reduced by 33 per cent., but also the oil fuel compared with coal requires per ton a very much reduced cubic capacity. The capacity thus saved is available for cargo space, or for the reduction in size and displacement, and therefore in power for a given speed.

A very considerable saving is effected by the reduction of the number of firemen required, and also in the rapidity of loading liquid fuel as compared with the time required for bunkering coal. Space for crew accommodation is reduced.

Where occasion arises for a sudden alteration in the load or power, oil fuel is much more suitable than coal, as considerably less time is occupied in adjusting consumption to suit the variation in the rate of evaporation required from the boilers.

The burners can be so adjusted under all normal conditions that the installation shall be practically smokeless, and they should be so adjusted that the slightest possible trace of smoke is apparent at the chimney. This is preferable to the adoption of an absolutely smokeless installation, where an excess of air may be ad-

mitted to the furnace without means of detection, a condition which precludes the obtaining of the maximum of economy.

It has been found in practice that where marine installations have been converted from coal to oil burning, there has been a marked improvement in the ability to secure and maintain a higher speed than was the case with coal.

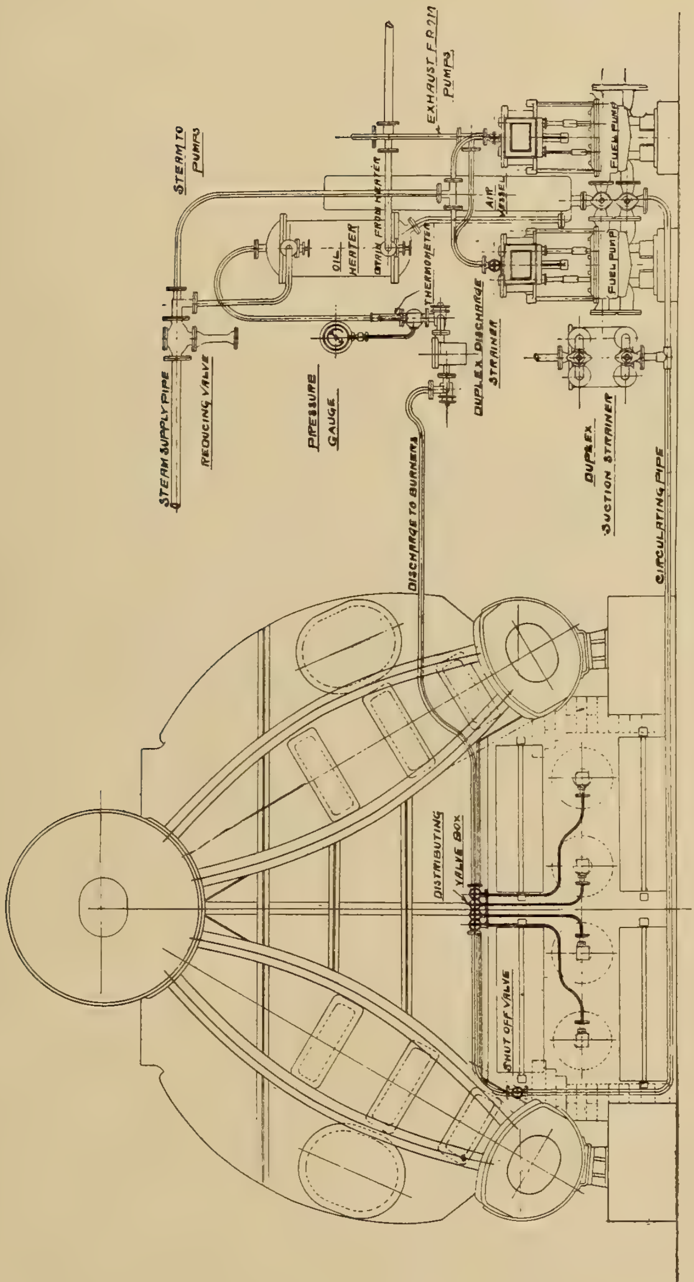
The oil is forced into the furnace in the shape of a conical spray of exceedingly fine particles, which burst into flame at a distance of 6 to 8 inches from the nozzle. The flame being conical, and there being no fire-bars fitted in the furnace, the whole circumference of the furnace is available for heating surface. This is a great advantage in the ordinary multitubular boiler, as the lower portion of the boiler becomes heated sooner than would be the case with coal, and consequently the circulation of water in the boiler is improved. Moreover, as the lower portion of the boiler is heated up uniformly with the upper portions, and as there is no inrush of cold air, since the furnace doors are never opened, there is practically none of that straining action which results from unequal expansion and contraction, due to rapid changes consequent on the opening of the door in coal stoking.

From the point of view of upkeep, a considerable economy is obtained. The repairs to the bunkers, a very considerable item in coal-burning ships of any age, is entirely obviated, as the liquid fuel is a preservative of steel. These advantages can be worked out upon a monetary basis; but the conditions vary in each trade, and it is, therefore, difficult to make a precise comparison. From data carefully taken from practical working on sea voyages, it is seen that in burning coal the cost per ton runs out at about 2s. for natural draught to 2s. 6d. for forced draught, including wages, victualling, repairs to furnace tools, stokehold plates, lamps, etc., but excluding the cost of the fuel, this being a separate item.

If oil fuel be adopted, the cost of burning per ton of oil would be about 9d. for natural draught to 7½d. for forced draught for moderate-sized cargo steamers, and as low as 4d. per ton in large liners. It must be borne in mind that not only is the cost per ton for burning greatly reduced, but the tons burnt is also less in the proportion of 1 of oil to 1½ or 1¾ of coal.

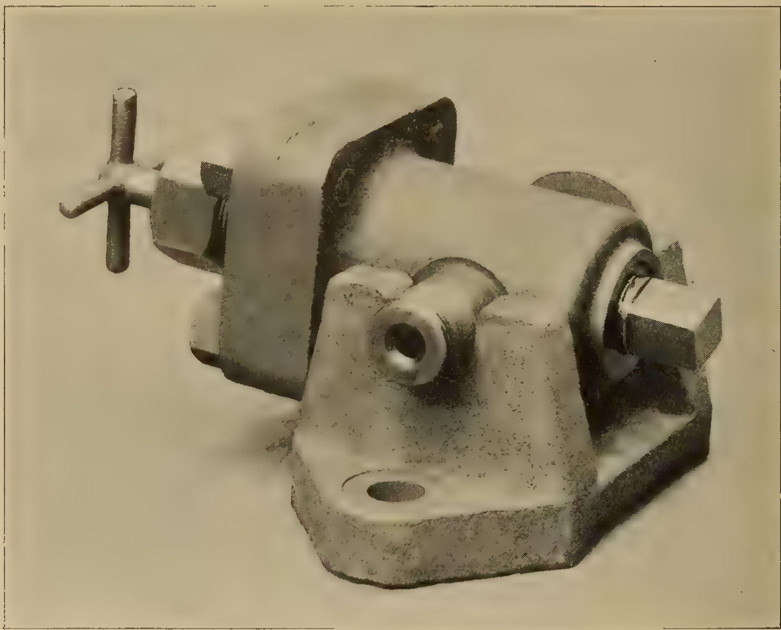
And now attention may be directed to the mechanical features. It is now many years since the first ship was installed for burning liquid fuel, and since that time marked improvements have been made in the methods of combustion. Most of the old installations were fitted with burners in which the oil was pulverized by means of a steam jet; and of this type perhaps the most usually adopted, at all events in steamers which were fitted out in the United Kingdom, was that known as the Rusden & Eele's oil burner. When the problem of adapting liquid fuel for marine purposes first attracted the attention of engineers, the Wallsend Slipway & Engineering Company, Ltd., took the subject up, recognizing its great potentialities, and carried out very elaborate experiments. The measure of their contribution towards developing and perfecting systems for burning oil is indicated by the fact that they have fitted between ninety and one hundred steamers with liquid fuel installations. The Rusden & Eele's burner was the first developed in the course of their work, and they applied it to a large number of steamers now trading in all parts of the world.

With this and other steam-jet burners, however, a considerable amount of steam was required to pulverize the oil, and it was consequently necessary to fit a special or greatly increased evaporating plant on board ship. Moreover, an appreciable portion of the heat units of the fuel consumed was absorbed in



THE KOERTING SYSTEM OF OIL BURNING AS APPLIED TO A WATER-TUBE BOILER

raising to furnace temperature the steam used for spraying the oil. The rarefied water vapour, too, displaced a certain portion of the air requisite for complete combustion. On a moderate computation 5 per cent. of the steam developed in the boilers was required for making up the water loss in steam spray. It was found desirable, therefore, to develop, if possible, a burner which would not require steam as a spraying agent.



THE KOERTING OIL BURNER

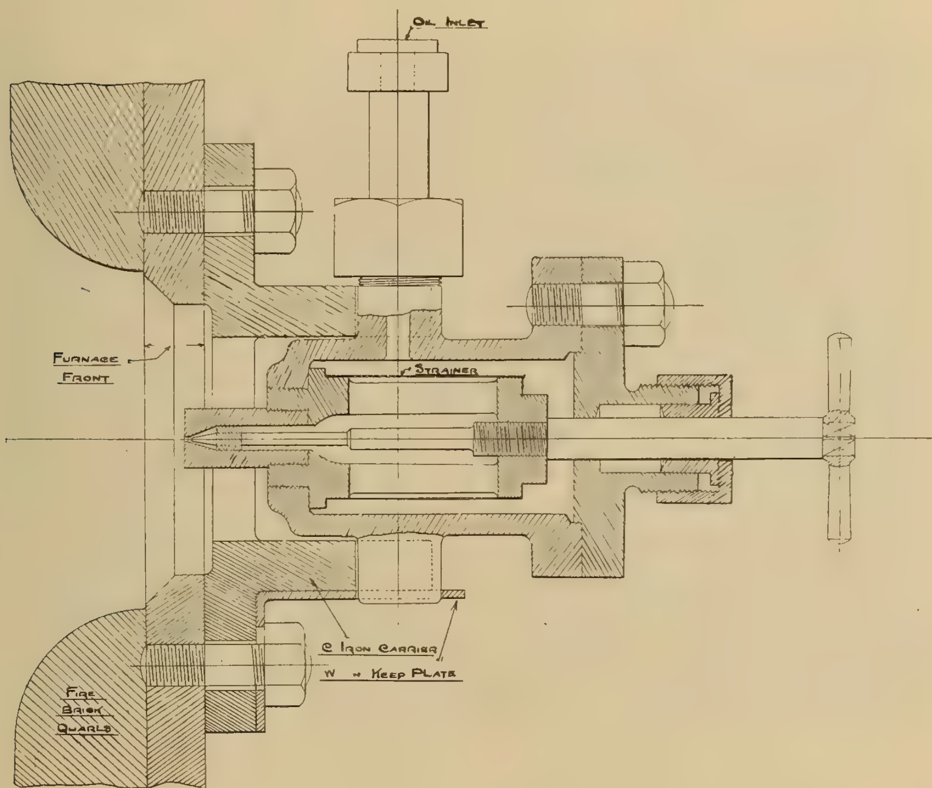
After carrying out many experiments with various designs of centrifugal sprayers, the firm, in 1902, undertook extensive experiments with the now well-known Körting burner. This burner is a centrifugal sprayer, through which the oil is forced into the furnace under pressure by means of special oil-fuel pumps. With this burner the only steam used is that needed for driving the pumps, and this involves no feed-water loss as the exhaust steam is returned to the main condensers. The results obtained during the experiments above referred to were so satisfactory that Körting sprayer or burners designed on similar principles have practically displaced steam-jet burners for marine oil-burning installations.

A typical oil-burning installation on the Körting system as applied on board ship is shown in the illustration. Special fuel pumps are installed in duplicate, either of which will deliver the fuel oil from the storage tanks to the burners. These pumps are also arranged to draw from the special oil bilge wells where any leakage of oil accumulates, and to discharge such accumulation overboard. In the event of one pump breaking down, the second pump can be immediately put to work, so that no inconvenience or delay results from such breakdown.

Where the oil contains any considerable quantity of water in suspension, which is sometimes the case, especially when the double-bottom ballast tanks are utilized as liquid fuel storage compartments, it is advisable to fit settling tanks in which such water can be separated from

the oil. When these tanks are fitted, further pumping facilities are required in order that the oil may be pumped from the storage tanks to the settling tanks before passing to the burners. These settling tanks are fitted in duplicate, so that the water may be separated from the oil in one tank while oil previously freed from water is being drawn from the other tank for combustion.

This separation of water from the oil is a primary element in success, and a first necessity is to ensure that the tank is completely filled from the storage reservoirs, so that when the vessels roll in a seaway there can be no disturbance of the contents. A second and important consideration is the application of a precise degree of heat, which facilitates the separation effectively and quickly. To this end the tanks are fitted with steam-heated coils, and here also the exhaust steam is returned to the condenser. The temperature of the oil is raised to not less than 180 degrees F. Extensive experiments have proved that at the above temperature the water is separated from the oil much more freely and completely than at a lower temperature. A less temperature, it was found, required a much longer time to separate the water from the oil, and even after a long period of heating at a lower temperature than 180 degrees it was found that a large proportion of the water was still in suspension.



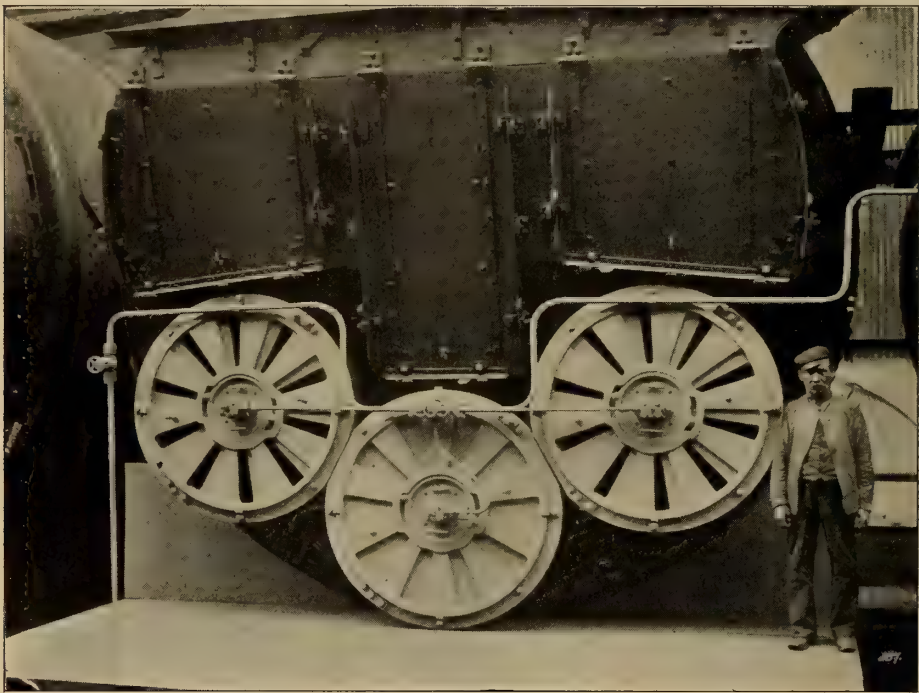
SECTION OF KOERTING OIL BURNER

The heating of the oil is kept up for five to six hours, or more if con-

venient. The water which precipitates to the bottom of the tank is then drawn off, after which the oil is ready for use. This arrangement of tanks is known as the Flannery-Boyd patent system of settling tanks, and the Wallsend Slipway & Engineering Company, Ltd., are the sole licensees. The fitting of these tanks is not, however, an essential feature of the Körting system of oil burning, and they are only necessary where there is likely to be a considerable amount of water in suspension in the oil.

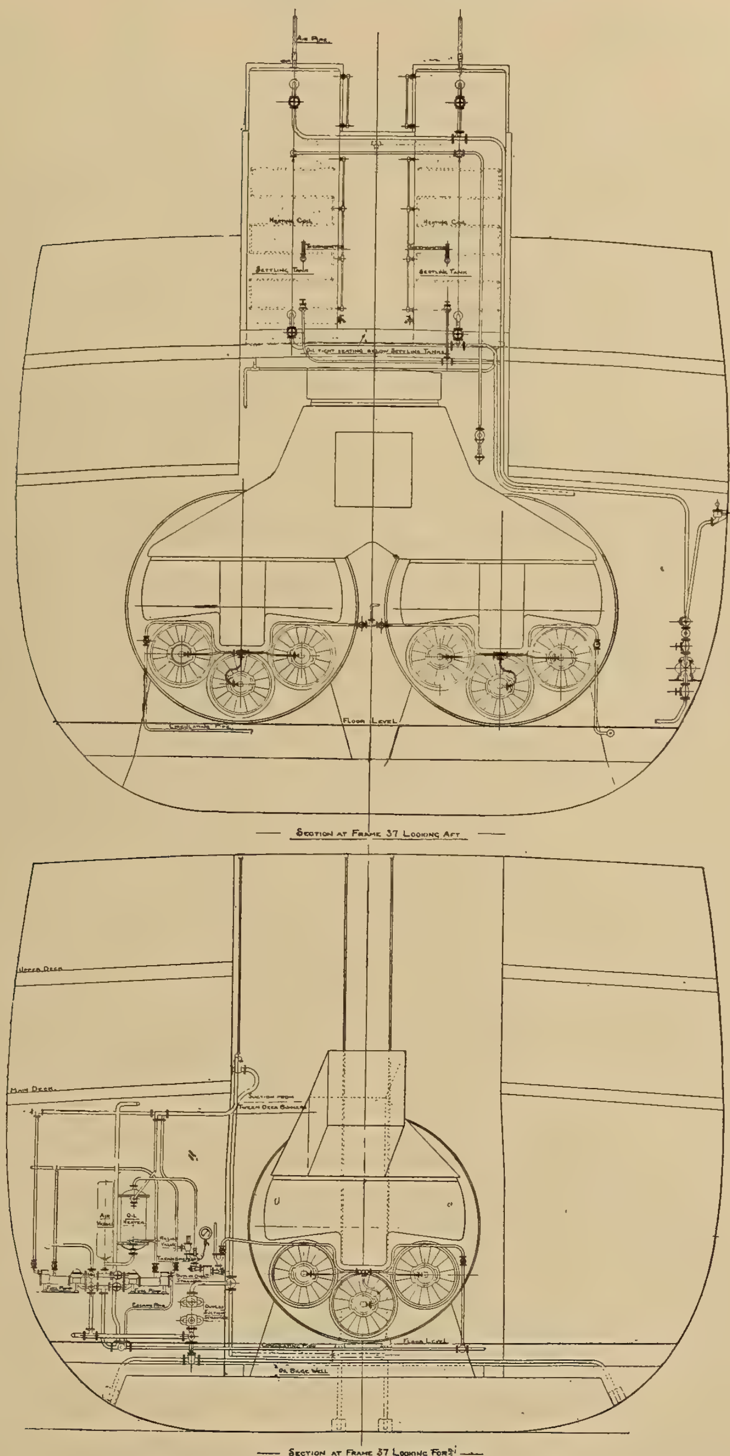
In all oil-burning installations it is necessary that the oil should be thoroughly filtered before consumption. This requirement has had special attention in the Körting system, there being fitted a large duplex strainer on the suction side of the oil-fuel pumps, so that the oil is filtered before entering the pumps. It is further filtered in a duplex strainer on the delivery side of the pumps, and finally in the burner itself. Both suction and delivery filters are made of the duplex type, so that one side may be disconnected for cleansing, while the other is doing all the duty.

The section of the Körting burner will enable the reader to clearly understand the arrangement of spindle, nozzle, and internal strainer. This last is of very fine mesh, so that there is no possibility of foreign matter finding its way into the nozzle.



FURNACE FRONTS ON MARINE BOILER EQUIPPED FOR BURNING OIL

Experience has shown that when the oil is heated before it is sprayed into the furnace, more economical results are obtained. In the Körting system a heater of the tubular type is fitted between the oil fuel pumps and the burners, and in it the oil is heated to the required temperature for giving the most economical results. The temperature is largely dependent upon the rate of combustion aimed at. During experiments under natural-



GENERAL ARRANGEMENT OF OIL-BURNING EQUIPMENT ON SHIPBOARD. WALLSEND SLIPWAY & ENGINEERING CO., LTD.

draught conditions 15 pounds of water were evaporated from and at 212 degrees F. when burning about 280 pounds of oil in one burner in a furnace which would be reckoned as having a 20-square-foot grate. The temperature in this case was 212 degrees F., and the pressure of oil at the nozzle 60 pounds per square inch. With best Mickley picked coal the evaporation per pound of coal in the same boiler was 9.31 pounds, so that in this instance, on comparative trials under natural draught, 1 pound of oil was equal to 1.61 pounds of the coal named.

With a closed stokehold on the same boiler nearly the same rate of evaporation per pound of fuel (14.06 pounds) was got under 1⅛-inch pressure on the water gauge, and the rate of oil fuel combustion was increased to 610 pounds of oil per burner, larger nozzles being used. To attain this result the pressure of oil at the nozzle had to be increased to 140 pounds per square inch, but as the disintegration of the liquid fuel increases with greater pressures, a lower temperature (110 degrees F.) was possible. Thus the rate of combustion can be enormously increased (in the cases quoted it was considerably more than doubled), while the rate of evaporation only fell off slightly. This is a great advantage for high-speed vessels. Nor was the economy in oil spray greatly affected, as the steam saved by the reduction in temperature partly compensated for that required for the increased pressure.

The arrangement of furnace fronts, together with the burners in position on a boiler front, is shown in the illustration. These furnace fronts are specially designed to suit the Körting system of oil burning. They are fitted with louvres, so that the admission of air can be adjusted to a nicety. The furnace front illustrated is for use with liquid fuel only. In the event of it being necessary for the installation to be so equipped as to be able to burn either coal or oil, the front can be made with the usual furnace door, and provision made for carrying a dead-plate. With this front the change can be made from oil burning to coal burning with the least possible alteration of arrangements and the minimum of time. This is an important consideration, as it is found in practice that it is convenient to be able to change rapidly from oil burning to coal burning, especially in steamers which are trading to all parts of the world, as it is found that sometimes oil fuel is cheaper than coal, and *vice versa*. The front portion of the furnace is bricked out to form a retort in which the oil is burnt.

The Körting burner is of extremely simple design, and the construction is such that a change of burners, when desirable, can be effected in a few minutes. It is also arranged to admit of rapid examination and cleaning. As the Körting burner does not require steam as a spraying medium, it is more suitable than a steam-jet burner, where oils containing water are used for fuel, as no further water is added in the spraying process, and therefore the flame is not so likely to be extinguished. It is an interesting fact that in Russia alone upwards of 4,000 centrifugal sprayers are in use.

Indeed, there is no unsurmountable obstacle from the mechanical point of view to the universal application of oil fuel for steam raising under all conditions. Even if the price of oil were much greater than coal there might be financial gain in ship propulsion, in view of the direct and indirect economies realizable, as already enumerated. The advisability of fitting our large Atlantic liners with oil-burning installations has been considered. This is quite feasible, but in this, as in so many cases, the question is one of economics, and concerns the certainty of obtaining the oil conveniently in sufficient bulk and at a price which would establish a financial superiority to coal.

A MEASURE OF THE VALUES OF WARSHIPS

By Sidney G. Koon, M. M. E.

NUMEROUS methods have been evolved for comparing the military values of one war vessel with those of another, and the qualities of a fleet with those of one to which it might conceivably be opposed. All these comparisons are based upon published statistics regarding the displacement, speed, protection and battery power of the various vessels under consideration, and some of them go still further into details regarding the character of ammunition-hoisting devices, the fuel capacity of the bunkers, and other items. Whatever method is adopted in any particular case is always liable to be attacked, because of the omission of certain items, or the predominance given to others which, in the eyes of other critics, they do not deserve. In general, the simpler the method the more open is it to adverse criticism. At the same time, methods which are not simple require much arduous labour for their application, and while the results may, to a certain extent, be more satisfactory, yet the extra degree of refinement can scarcely be said in many cases to pay for the extra labour.

In any case, the comparison is based on certain arbitrarily fixed proportionate values of the different features making up the military strength of the ship, and all refer to some common basis of reference. In some cases an epoch-making ship, like the British *Dreadnought,* is used as a type, and comparisons are instituted in such a way that the figures finally evolved may show as a percentage of the figure for the type ship. In other cases it will be found that an ideal ship is taken, usually much larger and more powerful than any ship in existence, and on this the figures are based. In either event the relative figures would have about the same proportion to each other, and, for the purpose of ready comparison in the present instance, the American battleship *Delaware* has been chosen as a standard or type ship.

This ship has a displacement of 20,000 tons; a designed sea speed of 21 knots; a battery consisting of ten 12-inch and fourteen 5-inch guns, of which ten 12-inch and seven 5-inch may be brought to bear upon one broadside; and armor protection, including a belt with a maximum thickness of 11 inches, turret armour 11 inches, and a protective deck of 2½ inches maximum thickness. The formula which it is proposed to use is:

$$F.\ V. = a \times \left(\frac{D}{1000} + 2\,(V - 11) + 4G + \tfrac{2}{3}\,(B + T + 2P)\right)$$

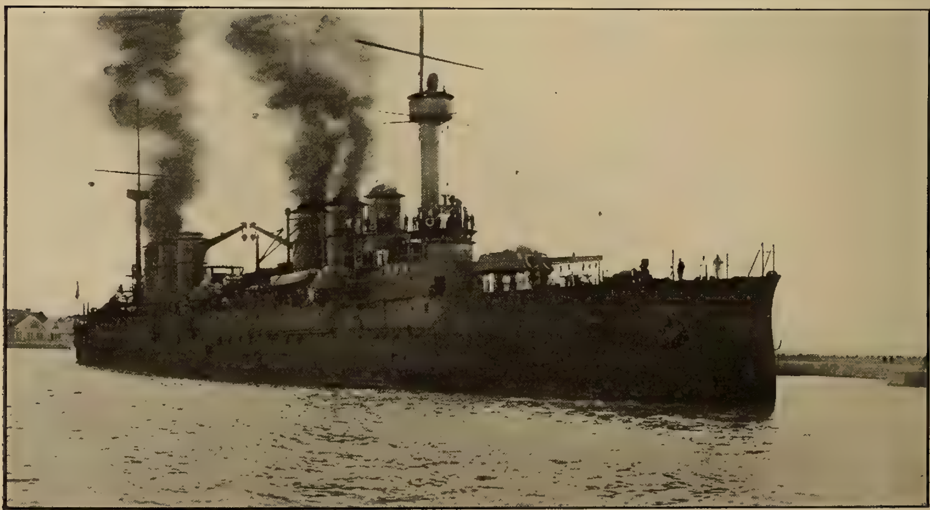
The first term within the parentheses represents the displacement in thousands of tons. That this is a factor worth considering in evaluating the fighting efficiency of a warship may be inferred from the fact that upon it depend to a very large extent the coal capacity and consequent steaming radius, the capacity for stores, the habitability at sea for long periods and in storms, and the steadiness as a gun platform. In each case the legend or normal displacement is taken.

The second term represents twice the excess of the speed in knots over 11 knots. This is an arbitrary figure, but it may well be recognized that differences of speed are of more

FRENCH BATTLESHIP REPUBLIQUE UNDER FULL SPEED

consequence than absolute speed, particularly in view of the fact that trial-trip speeds cannot ordinarily be expected in later service, when a ship has been some time away from a dockyard. In order to bring the speed factor up to a figure properly commensurate with its importance to a battleship, the figure 11 was chosen as the subtracting figure. This will give speed values varying in general from 12 to 20 for battleships, out of a total (for the *Delaware*) of 100. Trial-trip speeds are used.

The third and most important item is naturally the battery power. This may be figured out on the basis of the number of 12-inch guns, or their equivalent, and the total as given for the *Delaware* figures out at 42, or 42 per cent. of the total fighting value. The broadside is the only artillery figure worth using, in view of the fact that naval strategists seem



FRENCH ARMOURED CRUISER ERNEST RENAN

U. S. BATTLESHIP NEW JERSEY

U. S. BATTLESHIP OHIO

thoroughly agreed that future naval engagements will be fought broadside on. Regarding the evaluation of the different guns in terms of the 12-inch; this might be accomplished by comparing the muzzle energies, or by comparing the muzzle energies of all shots fired within a given period of time. Again, similar figures might be given for an assumed battle range, thus resulting in pushing largely into the background all the smaller pieces. As a simple means of getting at the result, it is proposed to use the muzzle energy of one round for all the large guns, and to assume that the greater proportionate falling off in energy of the smaller sized at battle ranges will be offset by their greater rapidity of fire.

Guns smaller than 4-inch may safely be neglected as being of no value at battle ranges, and guns not included in the table may readily be evaluated by interpolation. All guns of over 12 inches may be reckoned at unity, they being of the old, slow-firing type.

On this basis the various guns may be rated as follows:

11.8″	0.9	10.6″	0.65
11.	0.7	10.	0.6
9.45	0.5	9.2	0.45
8.	0.3	7.5	0.25
7.	0.2	6.7	0.17
6.4	0.15	6.	0.12
5.	0.07	4.7	0.05
4.	0.03		

The last term in our expression represents the maximum thickness of broadside armour added to the maximum thickness of turret or barbette armour and to twice the maximum thickness of deck armour. This does not take account of the extent to which the sides of the vessel are covered with armour, sacrificing exactness on this score in favour of an immensely increased simplicity of application.

TABLE I.

Navy.	Ship.	Tons.	Speed.	Guns.	Armour.	Total.
United States	*Delaware**	20.	20.	42.	18.	100.
"	*Michigan**	16.	15.	32.	19.3	82.3
"	*Connecticut*	16.	15.	25.6	20.3	76.9
"	*Virginia*	14.9	16.2	26.1	18.7	75.9
England	*Dreadnought*	17.9	20.2	32.	18.3	88.4
"	*Indomitable*	17.3	28.	33.2	13.3	91.8
"	*Lord Nelson*	16.5	14.8	25.	18.7	75.
"	*King Edward VII*	16.3	15.6	22.	16.7	70.6
France	*Danton*	18.4	16.	28.	18.6	81.
"	*Liberté**	14.6	16.8	19.4	19.9	70.7
Germany	*Nassau**	18.	16.	37.7	18.7	90.4
"	*"F"**	19.2	26.	33.6	13.7	92.5
"	*Deutschland*	13.	14.9	16.	17.6	61.5
Japan	*Satsuma*	19.5	19.	31.6	15.3	85.4
"	*Katori*	16.2	17.4	23.7	16.	73.3
"	*Tsukuba*	13.8	20.6	20.1	13.3	67.8
Italy	*New**	16.5	23.	22.4	16.5	78.4
"	*Roma*	12.4	22.	15.2	17.2	66.8
Russia	*Emperor Paul II.**	17.2	14.	25.2	14.7	71.1
"	*Rurik*	15.	21.	16.4	13.3	65.7

* Under construction

TABLE II.

UNITED STATES.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
2	*Delaware* (*a*)	100.	.....	200.	
2	*Michigan*	82.3	.....	164.6	
6	*Connecticut*	76.9	461.4	.....	
5	*Virginia*	75.9	379.5	.....	
2	*Idaho*	67.2	134.4	.....	
3	*Missouri*	67.	201.	.....	
3	*Illinois*	55.8	167.4	.....	
2	*Kentucky*	58.9	117.8	.....	
1	*Iowa*	.....	54.5	.....	
3	*Oregon*	42.7	128.1	.....	
29			1,644.1	364.6	2,008.7
	ARMORED CRUISERS.				
4	*Washington*	65.	260.	.....	
6	*Maryland*	57.8	346.8	.....	
3	*St. Louis*	44.4	133.2	.....	
1	*Brooklyn*	.....	33.1	.....	
1	*New York*	.....	31.1	.....	
15			804.2	.....	804.2
44	Grand totals		2,448.3	364.6	2,812.9

a Two more authorized and soon to be laid down.

GREAT BRITAIN.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
3	*St. Vincent* (*e*)	92.5	.....	277.5	
3	*Superb*	91.9	.....	275.7	
3	*Inflexible*	91.8	275.4	.....	
1	*Dreadnought*	88.4	88.4	.....	
2	*Lord Nelson*	75.	150.	.....	
8	*King Edward VII*	70.6	564.8	.....	
8	*London*	55.9	447.2	.....	
5	*Duncan*	63.8	319.	.....	
2	*Swiftsure*	61.9	123.8	.....	
6	*Canopus*	50.5	303.	.....	
9	*Majestic*	45.5	409.5	.....	
8	*Revenge*	44.	352.	.....	
1	*Renown*	.....	32.6	.....	
2	*Centurion*	32.8	65.6	.....	
61			3,131.3	553.2	3,684.5
	ARMORED CRUISERS.				
3	*Minotaur*	60.8	182.4	.....	
2	*Black Prince*	57.	114.	.....	
4	*Natal*	56.4	225.6	.....	
6	*Antrim*	50.1	300.6	.....	
10	*Essex*	47.6	476.	.....	
4	*Drake*	58.7	234.8	.....	
6	*Cressy*	45.6	273.6	.....	
35			1,807.	.....	1,807.
96	Grand totals		4,938.3	553.2	5,491.5

e A fourth soon to be laid down.

GERMANY.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
7	*Nassau*	90.4	.....	632.8	
5	*Deutschland*	61.5	307.5	.....	
5	*Elsass*	60.6	303.	.....	
5	*Wettin*	52.7	263.5	.....	
5	*Kaiser*	44.6	223.	.....	
4	*Worth*	35.9	143.6	.....	
31			1,240.6	632.8	1,873.4
	ARMORED CRUISERS.				
1	*"F"* (*b*)	.....	.....	92.5	
1	*"E"*	.....	.....	66.7	
2	*Scharnhorst*	56.3	112.6	.....	
4	*Roon*	46.9	187.6	.....	
1	*Prince Heinrich*	35.6	35.6	.....	
1	*Furst Bismarck*	41.	41.	.....	
10			376.8	159.2	536.
38	Grand totals		1,617.4	792.	2,409.4

b Really, a fast battleship; a second is about to be laid down.

FRANCE.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
6	*Danton*	81.	.....	486.	
4	*Liberté*	70.7	282.8	.....	
2	*République*	71.3	142.6	.....	
1	*Suffren*	.....	49.3	.....	
3	*Gaulois*	48.	144.	.....	
2	*Massena*	42.1	84.2	.....	
3	*Carnot*	37.8	113.4	.....	
1	*Brennus*	.....	40.9	.....	
22			857.2	486.	1,343.2
	ARMORED CRUISERS.				
2	*Quinet*	59.	.....	118.	
1	*Renan*	.....	59.	.....	
1	*Michelet*	.....	55.2	.....	
3	*Gambetta*	56.2	168.6	.....	
4	*Marseillaise*	43.	172.	.....	
3	*Montcalm*	39.8	119.4	.....	
3	*Kléber*	37.9	113.7	.....	
1	*Jeanne d'Arc*	.....	39.5	.....	
18			727.4	118.	845.4
40	Grand totals		1,584.6	604.	2,188.6

JAPAN.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
4	*Satsuma*	85.4	85.4	256.2	
2	*Kurama*	68.8	68.8	68.8	
2	*Tsukuba*	67.8	135.6	.....	
2	*Katori*	73.3	146.6	.....	
1	*Mikasa*	.....	60.6	.....	
2	*Asahi*	56.9	113.8	.....	
1	*Fujiyama*	.....	56.3	.....	
1	*Iwami* (*c*)	.....	61.9	.....	
2	*Sagami* (*c*)	49.8	99.6	......	
1	*Hizen* (*c*)	.....	50.	.....	
1	*Tango* (*c*)	.....	37.4	.....	
19			916.	325.	1,241.
	ARMORED CRUISERS. (*d*)				
2	*Kasuga*	46.1	92.2	.....	
2	*Yakuma*	39.4	78.8	.....	
4	*Tokiwa*	41.6	166.4	.....	
1	*Aso* (*c*)	.....	36.7	.....	
9			374.1	.....	374.1
26	Grand totals		1,290.1	325.	1,615.1

c Ex-Russian ships. *d* Two armored cruisers of great power about to be laid down.

ITALY.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
2	*New* (*f*)	78.4	.....	156.8	
4	*Roma*	66.8	200.4	66.8	
2	*Margherita*	66.4	132.8	.....	
2	*Filiberto*	43.7	87.4	.....	
3	*Sardegna*	35.9	107.7	.....	
13			528.3	223.6	751.9
	ARMORED CRUISERS.				
4	*Amalfi*	58.8	.....	235.2	
3	*Garibaldi*	39.9	119.7	.....	
7			119.7	235.2	354.9
20	Grand totals		648.	458.8	1,106.8

f Two more are in prospect.

RUSSIA.

		Each.	Built.	Building.	Total.
	BATTLESHIPS.				
2	*Emperor Paul I*	71.1	71.1	71.1	
2	*Evstavi*	62.	124.	.....	
1	*Slava*	.....	65.8	.....	
1	*Tsarevitch*	.....	65.1	.....	
1	*Panteleimon*	.....	47.1	.....	
1	*Tri Sviatitelia*	.....	42.7	.....	
1	*Georghi*	.....	36.6	.....	
9			452.4	71.1	523.5
	ARMORED CRUISERS.				
1	*Rurik*	.....	65.7	.....	
3	*Bayan*	42.5	85.	42.5	
1	*Gromoboi*	.....	36.5	.....	
1	*Rossia*	.....	37.	.....	
6			224.2	42.5	266.7
15	Grand totals		676.6	113.6	790.2

The factor outside the parentheses is an age factor, and may be taken to be unity for all vessels launched in and since 1901; 0.8 for ships launched in 1896 to 1900, inclusive; 0.6 for ships launched in 1890 to 1895, inclusive; and 0.4 for all earlier ships. This takes account of the inferior quality of armour fitted to earlier ships; also of low muzzle velocities and slow-firing weapons; of deterioration of structure and machinery, etc., and, in general, all elements dependent upon age.

On this basis fighting values have been computed for a number of the most prominent war vessels of the several powers. These are given in the tabulated statement on page 155. It will be seen that the *Dreadnought,* with an efficiency figure of 88.4, and the *Indomitable* class, with 91.8, are the most powerful vessels at present afloat. The American battleship *Michigan,* which has recently taken the water, and the Japanese *Satsuma* stand very high, with 82.3 and 85.4 units, respectively. The *Connecticut,* the *Virginia,* and the *Lord Nelson,* with just over 75 units each, ap-

BATTLESHIP "ELSASS." IMPERIAL GERMAN NAVY

pear to be about equally efficient.

The second table gives the final results for all the important war vessels of each of the seven most powerful navies. In the latter case nothing is included except battleships and armoured cruisers launched in 1890 or later, and the figures are divided into two sections, containing ships ready for service, and totals including ships under construction but not yet near completion. The third table is a summation of the second.

The figures given in Table III. show both the total figures for battleships and armoured cruisers now completed or practically completed for service, and figures for all such vessels built and building. It will be seen that Great Britain has a decided lead in every respect, and that the fighting value of the British fleet, both present and prospective, is equivalent to the value of any two of the other powers combined. The United States stands unquestionably second, with France and Germany fighting very hard for third place. The other powers are considerably lower in the scale, Japan having a good lead over both Italy and Russia, and Russia being slightly ahead of Italy at the present time, but considerably behind when the new Italian programme is taken into consideration. The Russians also have a large building programme, but its extent and nature are very imperfectly known, and when we consider the limitations imposed by the fact that several of the Russian battleships are locked up in the Black Sea, we may safely neglect the new programme in computing the relative Russian strength.

FRENCH ARMOURED CRUISER LEON GAMBETTA

One point brought out very prominently in these tables is the splendid average figure shown for the American ships. The battleships at present in service are, on the average, far superior to those of any of the other powers; the armoured cruisers are much ahead of any except the British, and are well ahead of those; and the total average is markedly ahead of any of our competitors. This position is not changed by the addition of ships under construction, except that the very heavy batteries of the two new German armoured cruisers (really, fast battleships) bring the figure for these vessels in the German navy up to such a value as to place the average equal to that

ITALIAN CRUISER AMALFI

JAPANESE BATTLESHIP KATORI AT FULL SPEED

TABLE III.

All Ships.	Battleships.			Armoured Cruisers.			Totals.		
	No.	F. V.	Avg.	No.	F. V.	Avg.	No.	F. V.	Avg.
Great Britain	61	3684.5	60.4	35	1807.	51.6	96	5491.5	57.2
United States	29	2008.7	69.3	15	804.2	53.6	44	2812.9	63.9
Germany	31	1873.4	60.4	10	536.	53.6	41	2409.4	58.8
France	22	1343.2	61.1	18	845.4	47.	40	2188.6	54.7
Japan	19	1241.	65.3	9	374.1	41.6	28	1615.1	57.7
Italy	13	751.9	57.8	7	354.7	50.7	20	1106.8	55.3
Russia	9	523.5	58.2	6	266.7	44.5	15	790.2	52.7
Completed Ships Only.									
Great Britain	55	3131.3	56.9	35	1807.	51.6	90	4938.3	54.9
United States	25	1644.1	65.8	15	804.2	53.6	40	2448.3	61.2
Germany	24	1240.6	51.7	8	376.8	47.1	32	1617.4	50.5
France	16	857.2	53.6	16	727.4	45.5	32	1584.6	49.5
Japan	15	916.	61.1	9	374.1	41.6	24	1290.1	53.8
Italy	10	528.3	52.8	3	119.7	39.9	13	648.	49.8
Russia	8	452.4	56.6	5	224.2	44.8	13	676.6	52.

of the United States. In battleships, however, and in the total of fighting vessels, the United States average is unapproached.

PISTON ENGINES VERSUS TURBINES ON THE ATLANTIC

By R. Caird, LL. D., M. Inst. C. E., F. R. S. E.

OF late years propulsion by marine turbines has been so prominently before the public and has taken such hold of popular imagination that the older-fashioned reciprocating type of engine has fallen from the place of pride into undeserved disfavour.

The overcoming of the difficulties which from the days of Watt appeared insuperable in producing a marine turbine engine mechanically efficient and economical, first accomplished by the Hon. C. A. Parsons in comparatively recent years after innumerable attempts by capable engineers during more than a century, naturally carried the public by storm.

There was an element of romance, of heroic daring, in the adoption of the system for the big Cunarders after so short a period of trial, and that on a scale, too, so apparently inadequate that the venture appeared to many foolhardy. But so much confidence was felt in the commission appointed by the Admiralty and the Cunard Company to study the question and decide upon the design that the shares of the company not only did not fall in price, but slightly appreciated in value during the construction of these express steamers.

A very interesting paper was read at this year's spring meeting of the Institution of Naval Architects by Mr. Bell, of Clydebank, who was responsible for the design and construction of the engines of the *Lusitania,* giving a very full account of that vessel's performance on the initial trials as regards steam efficiency. From that paper most of the figures referring to these express steamers have been taken, and where assumptions are made, in the absence of information, the reasons for making them are given.

When the problem of designing these steamers to cross the Atlantic at an average speed of twenty-five knots was submitted to the Commission, the blue ribbon of the Atlantic was held by the *Kaiser Wilhelm der II.* with an average speed of 23.58 knots.

Four of the German steamers were doing the passage to and from America at the rate of 23½ knots, whereas the best British record was held by the Cunard *Campania* and *Lucania,* built fifteen years ago, and is about a knot and a half slower than the German boats.

Even if dimensions were not increased, the enhanced speed, from 23½ to 25 knots, would require an increase in power of about 25 per cent., or, say, 10,000 indicated horse-power.

Or, as compared with the *Campania,* an increased power of about 50 per cent. would be required, or nearly 15,000 indicated horse-power.

The exigencies of weight to be carried, due to the increased weight of machinery and boilers and of fuel, both in the proportions given above, called for an expansion of dimensions.

The following table shows the principal dimensions and technical particulars of the leading Atlantic liners built during the last fourteen years, including the *Campania* and *Lusitania.*

It is noteworthy that in fixing the dimensions of the *Kaiser Wilhelm II.*[*] and of the *Lusitania* the naval architects have been careful to se-

COMPARATIVE TABLE OF ATLANTIC GREYHOUNDS.

Vessel	Campania.	Kaiser Wilhelm der Grosse.	Oceanic.
Built	1893	1898	1899
Owners	Cunard	North German Lloyd	White Star
Length (extreme)	622 feet 0 inches	648 feet 0 inches	704 feet 0 inches
Length (B. P.)	600 feet 0 inches	625 feet 0 inches	685 feet 0 inches
Breadth	65 feet 3 inches	66 feet 0 inches	68 feet 0 inches
Depth	41 feet 6 inches	43 feet 0 inches	49 feet 6 inches
Gross tonnage	12,500.0	14,349.0	17,274.0
Load draft	25 feet 0 inches	28 feet 0 inches	32 feet 6 inches
Displacement	18,000 tons	20,880 tons	28,500 tons
Passengers	1st, 600; 2d, 400; 3d, 700	1st, 590; 2d, 354; 3d, 640	1st, 410; 2d, 300; 3d, 1,000
Boilers	12 D. E. and 1 S. E.	12 D. E. and 2 S. E.	15 D. E.
Heating surface	82,000 square feet	84,285 square feet	17,686 square feet
Fire grate	2,630 square feet	2,618 square feet	1,962 square feet
Working pressure	165 lbs. per square inch	178 lbs. per square inch	192 lbs. per square inch
Engines (sets)	Triple (2)	Triple (2)	Triple (2)
Engine dimensions	Two Two 37×79×98 ins. 5 feet 9 inches	Two Two 52×89.7×96.4 ins. 5 feet 8.8 inches	Two Two 47½×79×93 ins. 6 feet 0 inches
Speed	22.0 knots	22.5 knots	20.0 knots
I. H. P.	30,000	30,000	27,000

Vessel	Deutschland.	Kronprinz Wilhelm.	Kaiser Wilhelm II.
Built	1900	1901	1902
Owners	Hamburg-American	North German Lloyd	North German Lloyd
Length (extreme)	684 feet 0 inches	663 feet 0 inches	706 feet 6 inches
Length (B. P.)	662 feet 9 inches	....	....
Breadth	67 feet 0 inches	66 feet 0 inches	72 feet 0 inches
Depth	44 feet 0 inches	43 feet 0 inches	52 feet 6 inches
Gross tonnage	16,802.0	15,000.0	20,000.0
Load draft	29 feet 0 inches	29 feet 0 inches	29 feet 0 inches
Displacement	23,620 tons	21,300 tons	26,000 tons
Passengers	1st, 693; 2d, 302; 3d, 288	1st, 650; 2d, 350; 3d, 600	1st, 775; 2d, 343; 3d, 770
Boilers	12 D. E. and 4 S. E.	12 D. E. and 4 S. E.	12 D. E. and 7 S. E.
Heating surface	85,468 square feet	93,865 square feet	107,643 square feet
Fire grate	2,188 square feet	2,702 square feet	3,121 square feet
Working pressure	220 lbs. per square inch	213 lbs. per square inch	225 lbs. per square inch
Engines (sets)	Quadruple (2)	Quadruple (2)	Quadruple
Engine dimensions	Two Two 36.6×73.6×103.9×106.3 ins. 6 feet 0.8 inches	Two Two 34.2×68.8×98.4×102.3 ins. 5 feet 10.8 inches	Two Two 37.4×49.2×74.8×112.2 ins. 5 feet 10.8 inches
Speed	23.5 knots	23.5 knots	23.73 knots
I. H. P.	36,000	36,000	40,000

Vessel	Caronia.	Carmania.	Lusitania.
Built	1904	1905	1907
Owners	Cunard	Cunard	Cunard
Length (extreme)	678 feet 0 inches	678 feet 0 inches	785 feet 0 inches
Length (B. P.)	650 feet 0 inches	650 feet 0 inches	760 feet 0 inches
Breadth	72 feet 0 inches	72 feet 0 inches	89 feet 6 inches
Depth	52 feet 0 inches	52 feet 0 inches	60 feet 4½ inches
Gross tonnage	21,000.0	19,524.0	32,500.0
Load draft	32 feet 0 inches	33 feet 3 inches	33 feet 6 inches
Displacement	29,800 tons	30,000 tons	38,000 tons
Passengers	1st, 300; 2d, 350; 3d, 1,000	1st, 300; 2d, 326; 3d, 1,000	1st, 552; 2d, 460; 3d, 1,186
Boilers	8 D. E. and 5 S. E.	8 D. E. and 5 S. E.	23 D. E. and 2 S. E.
Heating surface	52,139 square feet	52,130 square feet	158,352 square feet
Fire grate	1,298 square feet	1,297 square feet	4,048 square feet
Working pressure	210 lbs. per square inch	195 lbs. per square inch	195 lbs. per square inch
Engines (sets)	Quadruple (2)	Turbines	Turbines
Engine dimensions	39×54½×77×110 ins. 5 feet 6 inches	Driving 3 shafts	Driving 4 shafts
Speed	19.5 knots	20.0 knots	25.0 knots
I. H. P.	21,600	22,000 (S. H. P.)	65,500 (S. H. P.)

lect the most suitable lengths and coefficients of fineness, having regard to the maximum designed speed.

A hollow in the resistance curve occurs at 23.7 knots in the case of the former vessel, and at 25 knots in that of the latter.

So that in comparing performances it is safe to assume that both vessels are, as regards size and form, respectively, as suitable as, in the present state of our knowledge, it is possible to design them.

Many years ago Mr. Hök gave in tabular form the relations between length, speed and block coefficients in the best practice. The writer of the present article gave these particulars in diagram form in a paper on "Propeller Diagrams," contributed to the Institution of Engineers and Shipbuilders in Scotland in 1895. Since then, experience has proved the accuracy of Mr. Hök's determinations, and it is remarkable that the designed speeds of the two steamers under review correspond exactly to the figures in his table.

There are several methods of comparison of the performances of steamers. One very commonly used is that afforded by what is known as the Admiralty or $D^{2/3}$ coefficient, which assumes that the coefficient varies directly as the product of the $\frac{2}{3}$ power of the displacement and the cube of the speed and inversely as the indicated horse-power. Applying this to the German steamer and to the Cunarder at maximum speeds, the respective coefficients work out at 293 and 257. That is to say, on this criterion the piston engine is 14 per cent. more efficient than the turbine.

For strict comparison an allowance should be made in favour of the German steamer, the coefficient being *ipso facto* higher for greater displacement.

In this calculation the shaft horse-power, as given in Mr. Bell's paper, has been taken as 97 per cent. of the indicated horse-power.

It is difficult to determine exactly what the percentage should be, but there is not much range for error in the above if we consider that the German tests of the ratio of shaft horse-power to indicated in reciprocating engines was less than 94 per cent.—exactly 93 per cent. by torsion meter tests in the case of the *Kaiser Wilhelm II.*

The low propulsive efficiency of the *Lusitania,* as given in Fig. V. of Mr. Bell's paper, and the exceptionally low rate of coal consumption, point to either inaccuracies in the torsion-meter readings or to a very high engine-efficiency, or to both. But the coefficients given above would not be materially affected even if the initial and working friction of these turbine engines were taken as nil, provided that a proper correction were made for greater displacement.

The steam efficiency of the *Lusitania* is so high that the reason for the low general efficiency found from the $D^{2/3}$ coefficient must be sought for elsewhere.

It seems that it must be looked for in the application of the power through the propellers, whether in the propeller efficiency or in the thrust deduction due to the position of the propellers it is impossible to say without full information.

It must be borne in mind that the *Kaiser Wilhelm* has two screws and the *Lusitania* four, and the wing propellers being less immersed than the centre ones, have less hydraulic head and are probably less efficient.

Be that as it may, the fact remains that the *Lusitania* is about 14 per cent. less efficient than the *Kaiser Wilhelm* on the Admiralty coefficient test.

There is another test which may be applied, that of the coal consumed for every 1,000 tons displacement per 1,000 nautical miles run per knot speed.

The *Lusitania* takes 1.93 tons and the *Kaiser* 1.7 tons, the former being 13.5 per cent. less efficient as tested by this formula.

This agrees very closely with the

figure got by the Admiralty constant, and, as in that case, some further credit is due to the German steamer in respect of the *Lusitania's* greater displacement.

Speaking generally, the *Kaiser* is about 15 per cent. more efficient than the *Lusitania.*

What are the benefits to set off against this loss? Of course the appeal to the imagination of the public, alluded to at the outset of this paper, has an advertising value. It is questionable, however, if this will be lasting, or even if it has proved to be of much value. It is claimed for turbines that an almost entire absence of vibration may be counted upon; but experience does not bear this out, and it is difficult to see how the effect of the couples set up by varying thrusts in a horizontal plane exerted through the shafts can be obviated.

Another advantage claimed for turbine engines is the reduction of weight of machinery; and the claim must be conceded, chiefly on account of the reduction of boiler weight, due to decreased pressure in the case of the turbine.

It does not seem, however, that in large installations much reduction in weight has been effected: and even if it had been, the greater amount of coal to be carried, due to the lower efficiency, would more than counterbalance the gain.

It may be interesting to consider for a moment what economies might be effected in a *Lusitania* fitted with piston engines.

It is somewhat difficult to put the necessary calculations sufficiently clear for general comprehension within the space available in any other than tabular form, but a comment running through the figures may prove useful.

Taking the mean displacement at 37,080 tons, draught 32 feet 9 inches, the effective horse-power from Mr. Bell's diagram is 31,700. For prudence, taking the resistance due to the bosses with three propellers as 5 per cent. more than with four, the shafts being of greater diameter, and assuming a hull efficiency of 90 per cent., the thrust horse-power works out at 36,983.

With three propellers of 25 feet diameter, having 200 square feet surface on three blades, or a surface ratio of 40.7 per cent. and 80 revolutions per minute, set at a pitch of 35 feet, the apparent slip is 9.5 per cent., and the propeller efficiency by Froude's latest curves nearly 74 per cent.

Assuming an engine efficiency of 90 per cent. and a propeller efficiency of 70 per cent. the indicated horse-power at 25 knots is 58,700; the Admiralty coefficient 296, and the propulsive coefficient 54 per cent. These efficiencies are all taken lower than those deduced from the best practice.

The horse-power passed through each shaft is less than that in the *Kaiser Wilhelm der II.*

Three sets of quadruple expansion engines of the following dimensions would be sufficient to develop the required power: Cylinders 51 inches, 73 inches and 103 inches; two of 103-inch; stroke 6 feet. Boiler pressure 215 pounds.

The coal consumption at 1.35 pounds per indicated horse-power per hour would be 850 tons per day, or 250 less than that of the big Cunarders—a saving sufficient to drive the C. P. R. *Empress of Britain* at 19½ knots.

Two of the Cunarder's double-ended boilers could be dispensed with. The following table shows approximately the actual and estimated trial results in the turbine and piston-engine cases respectively:

	Lusitania	Proposed
Speed, knots	25	25
Revolutions	186	80
Slip, per cent.	15.5	9.5
Shaft horse-power	65,500	52,830
Propulsion efficiency on shaft horse-power, per cent.	48.4	60

NAVAL ORDNANCE

By Lieutenant A. Trevor Dawson, R. N., M. I. C. E., M. I. Mech. E.

BATTLES are won by hitting hard and hitting often. This fact is now so universally recognized that there is less tendency than formerly to equip a ship on the principle that it is well to be able "to run away and live to fight another day." Consequently, ordnance has become the primary consideration in designing a warship. This does not, in any degree, tend to the depreciation of the work of the designers of the other essential qualities. A ship may be a gun platform; but its efficiency must necessarily depend upon its mobility, upon the facility with which the gun can be brought and kept in action at the required time and at the most advantageous range, and upon the protection afforded in order that the guns may continue in action notwithstand- a violent attack upon the ship as a gun platform. There is no intention, however, in this article to consider those questions, which are more appropriately discussed by other writers in this issue. The aim here is rather to review the progress made towards "hitting hard and hitting often" during the years that have elapsed since the last Marine Number of this magazine was published, and to describe the extensive and important improvements which have been evolved by continuous effort in connection with modern artillery.

That increased importance is attached to naval ordnance in the design of ships is easily proved by an examination of the items of cost in the completion for commission of ships of the line. The total cost of such ships has almost doubled during the past ten years, the ships of the *Majestic* class having been built for about £950,000 each, while the *Dreadnought,* according to the navy estimates, cost £1,760,000. An examination of the details in the navy estimates further shows that the aggregate cost in the modern battleship of gun mountings has increased fivefold. The sum spent on such machinery, apart from guns, in the case of the ships of the *Majestic* class, according to the navy estimates of that year, was £49,000, or about 5 per cent. of the total cost. In these vessels, however, there were only two turrets, and, therefore, two sets of gun-mounting machinery. When the vessels of the *King Edward VII.* class were designed a development was made, and instead of two turrets, six were fitted, two of them having twin 12-inch guns and four having a single 9.2-inch gun. The machinery for operating the guns in all these turrets cost about £220,000, equal to about 15 per cent. of the total cost of the ship. A still bigger step was taken in the *Lord Nelson* class, when eight turrets were fitted, two of them having twin 12-inch guns, four of them twin 9.2-inch guns and two with one 9.2-inch gun. The machinery for the eight turrets cost over £440,000, equal to 27 per cent. of the aggregate cost of the vessel. This last total is interesting when compared with the cost of the gun-mounting machinery in the *Dreadnought,* as it shows that the fitting of single guns in barbettes increases the cost, because the gun machinery in the turrets for twin 12-inch guns of the *Dreadnought* cost £88,000 less than the gun machinery of the *Lord Nelson* and made only 21 per

cent. of the total cost of the ship ready for commission. The difference in the number of turrets accounts for the increased cost. In all questions of defense cost must ever be secondary, although by no means a negligible consideration, and if it were established that the means for attack in the *Lord Nelson* class were more efficient than in the *Dreadnought* class the comparison would lose its significance. There are few, however, who regard the armament of the *Lord Nelson* class as even equal to that of the latest battleships, because while the 9.2-inch gun has a higher rate of fire, perhaps to the extent of 40 per cent., it has lower striking energy. Moreover, unity in calibre of the primary armaments confers such advantage as to further counterbalance the higher rapidity. In connection with these figures it is important to enforce the enormous capital involved in the construction of modern naval machinery, and it is satisfactory to reflect that in Great Britain the naval construction firms have shown so much enterprise in providing the necessary workshop equipment, which far exceeds the producing capacitv of any foreign nation and is more than capable of meeting immediately any possible large prospective requirements the Admiralty may have, and indeed leaves a large margin of producing facility to undertake those foreign orders which are such an important element in the employment of all classes of labour in this country.

BOW VIEW OF A MODERN BATTLESHIP, SHOWING THE FORWARD TURRET WITH TWO 12-INCH GUNS AND TWO SINGLE 10-INCH TURRETS AT THE SIDES

The five-fold increase in the cost of naval ordnance in the later ships as compared with those of ten years ago is more than outweighed by the addition to efficiency. If we take the

striking energy, it is found that, against the 9-inch modern hardened armour, the four guns of the *Majestic* class can only be effective at 7,100 yards range, whereas modern 12-inch guns can perforate the *Majestic* armour at 14,500 yards range. This fact alone proves that the money on ordnance has been well spent. It also incidentally brings home the exceeding danger of placing national trust upon ships of the *Majestic* class, because were a fleet of these ships to encounter even a comparatively small squadron of foreign ships of the *Dreadnought* era they would easily be annihilated. Again, in respect of rapidity of fire, the modern gun has enormous advantages. It is true that, largely through the ingenuity of the present British Naval Ordnance Department and other naval officers, mechanisms have been provided whereby accuracy has been greatly improved. The system of control for the guns has been so perfected as to enable the sight to be readily kept always on the object, securing a greater number of hits per unit of time even with the older guns. The average performance of all the ships of the *Majestic* class during the past year shows that the 12-inch gun originally built ten years ago gave 0.72 hits per minute, whereas the guns of the ships of the *King Edward VII.* class gave 0.97 hits per minute and the newer guns of the *Dreadnought* 1.31 hits per minute. We have thus a direct measure of the greater efficiency in rapidity of accurate fire of the latest weapons as compared with earlier ordnance when both are operated by men trained under the same conditions.

It thus becomes easy to appraise the relative collective energy of the ships of ten years ago and those of to-day. Reckoning only the hits per minute, it is found that the 12-inch guns in the *Majestic,* whose machinery cost £49,000, developed 95,100 foot-tons per minute. The four 12-inch guns and four 9.2-inch guns of the *King Edward VII.* class, costing four times the amount (over £220,000), developed about 275,700 foot-tons per minute, or three times the energy. In the case of the *Dreadnought,* the effective energy developed was more than six times greater. The figures evolved from official documents are tabulated:

TABLE OF ENERGY DEVELOPED IN TARGET PRACTICE

SHIPS.	Guns.	Cost of Gun. Mountings.	Muzzle Energy from One Round of Guns.*	Average Hits Per Minute in 1907 Practice.*	Muzzle Energy Developed of Hits Per Minute.*
CLASS.					
Majestic	4—12″	£49,000	132,080	.72	95,100
King Edward	4—12″ and 4—9.2″	220,000	239,860	.97 for 12″ and 1.48 for 9.2″	275,700
Lord Nelson	4—12″ and 10—9.2″	440,000	......	....	......
Dreadnought	10—12″	365,000	476,970	1.31	624,830

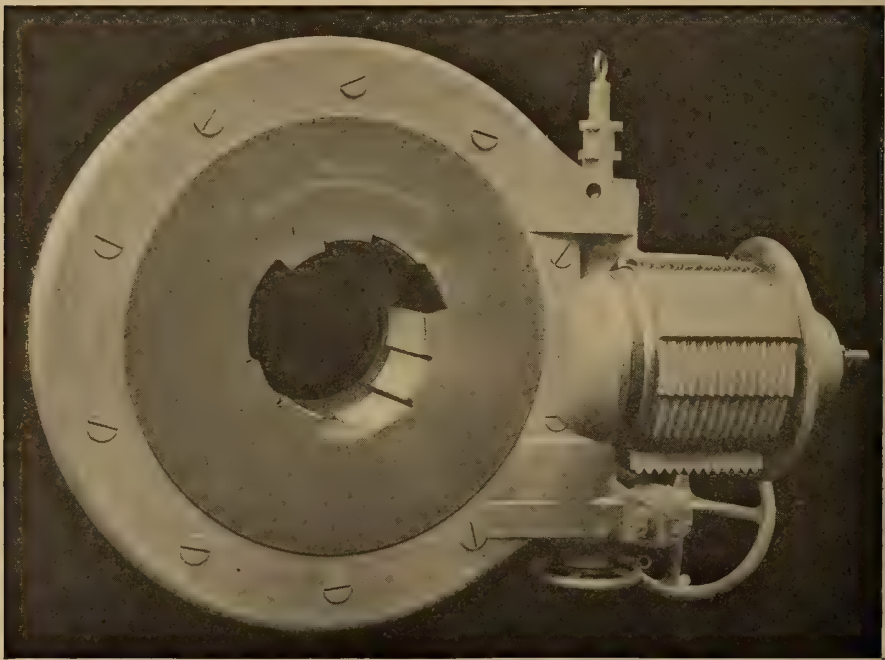
*Vide Brassey's Annual.

In reviewing the improvements which have led to this increased efficiency, the construction of guns may first be considered. The weapon of 12-inch calibre has, in ten years, been increased in length from 36 to 45 calibres, and still longer guns are being considered by many British and foreign ordnance firms. At the same time there has been adopted, in place of the old brown powder, an explosive compound of greater expansive properties, and therefore of increased propelling power, so that the projectile leaves the muzzle of the gun at a higher velocity. The more progressive Powers look for 3,000 feet per second, but several important naval authorities are still satisfied with 2,800 feet per second. There is no question, however, as to the safety of the higher velocity, and as it very materially decreases the

trajectory, increases the danger zone, and consequently minimizes the possibility of misses, the tendency must certainly be towards still higher velocities.

The method of constructing guns has not, perhaps, altered materially during the ten years, and there is still the same difference of opinion regarding the relative qualities of the wire-wound and steel-tube systems of construction. Guns on both principles are extensively made in Britain, although the British Government have continued their preference for the wire-wound gun. With both systems British gun-makers have had most satisfactory results. The weapons of the all-steel or ring construction of British manufacture have been tested to the extent of firing long series of rounds with full charges at 3,000 feet velocity, with no material loss of efficiency. Such a test suffices to establish the fact that the British makers are able to meet all demands for this construction of gun as well as for the well-tried wire-wound system.

Both systems have their advantages and disadvantages. There can be no question of the greater circumferential strength of the wire construction, as the wire itself gives a steel of greater tensile strength than rings, and the tension in winding can be so accurately regulated as to ensure uniform resistance to firing stress. There is thus absolute soundness in the material reinforcing the inner tubes. The all-steel or ring system, which was the original method, but was departed from to secure the many advantages of the compound steel and wire construction, is now in favour.



BREECH OPEN.—SHOWING THE VICKERS TYPE OF BREECH SCREW AS ADOPTED BY THE BRITISH AND OTHER GOVERNMENTS

Ten years ago, when cordite was beginning to be introduced, the charge for the 12-inch gun was 167 pounds; but to-day it is approximately double this. The maximum pressure within the guns generally has been consider-

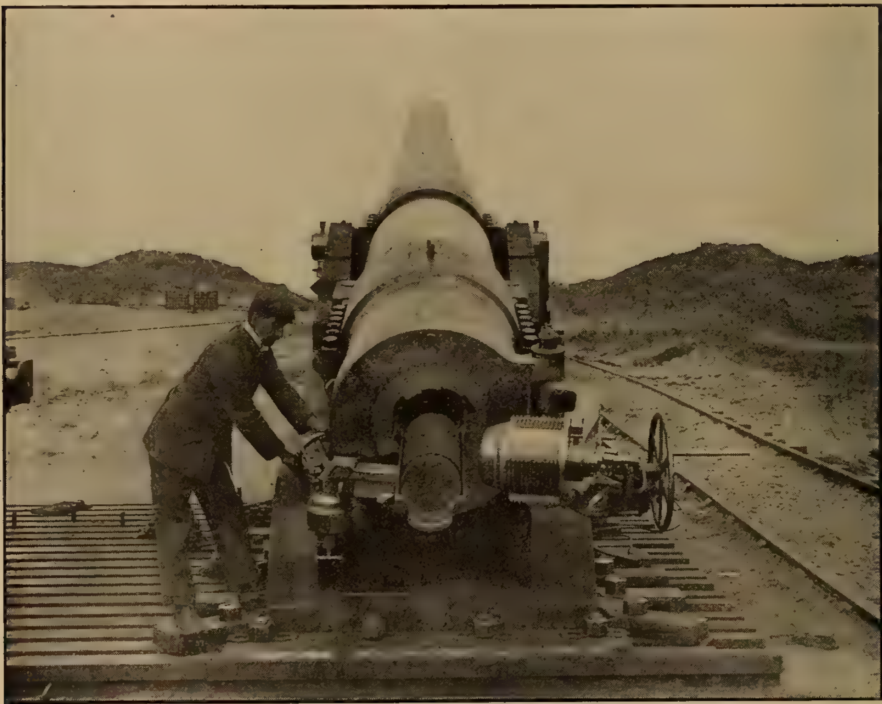
ably increased in some countries, up to 20 tons per square inch. This increased pressure has involved greater resisting power by the breech block, and during the ten years there has been introduced a new form of block which is very well shown in the illustrations. It will be seen that, by the division of the circumference of the block into twelve sections of different steps, it has been found possible to thread three-quarters of the circumference of the block of the 12-inch gun instead of one-half in the case of the old parallel screw block. The resistance to back pressure is correspondingly increased. The length of the block may thus be reduced for equal resisting power, and thus it has been found possible to reduce the length of the breech end of the gun.

The improvements in the mechanism for opening and closing the breech have greatly added to the accuracy and rapidity of fire. In the heavy guns, where a powerful mechanically-controlled gear is required, hydraulic and electric means have been applied. The hydraulic cylinder utilized for opening the breech is well shown in the view on page 174. The reciprocating motion of the ram is converted to rotary motion to suit the hinge of the breech block by means of a rack and pinion. In guns of 10 inches and less calibre the breech is worked by hand, and the sequence of operations is the same as with the hydraulically-actuated 12-inch mechanism. The one motion, either of hydraulic cylinder or gunner's arm, successively withdraws the firing gear, slides the bar to which it is connected laterally across the face of the carrier, rotates the breech block sufficiently to enable the screws to disengage its threads with those in the breech of the gun, and swings the block clear of the opening, leaving the gun open for the charge. The reverse action of the hydraulic

BREECH CLOSED.—WITH HAND-WHEEL FOR OPERATING THE OPENING AND CLOSING OF THE BREECH

mechanism or handle closes the breech.

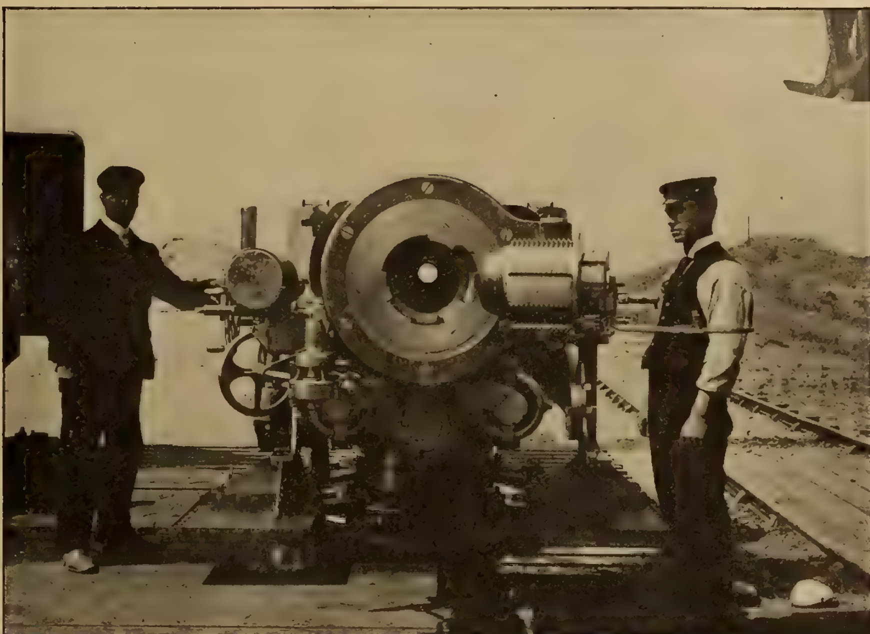
In order to facilitate the charging of some of the heavier guns, there are now fitted at the breech end trays mounted on a radial arm, which is actuated by worm and screw gear so that the shot may be swung into the opening of the breech. The tray enters the gun sufficiently far to obviate any possibility of the shot injuring the threads with which the screw block engages. This system has been fitted even to guns of 7.5-inch and 6-inch calibre; but as the weight of the projectiles for such guns is comparatively small, the radial arm and tray are swung into and out of the breech opening by hand. The 9.2-inch gun illustrated herewith shows the screw form of loading tray, while on page 173 there is another form of screw-operated radial arm mounted on a 7.5-inch gun. In this latter case it is possible to withdraw the screw gear and operate the tray by hand. The loading tray with screw gear is specially advantageous when the ship is rolling in a seaway.



MOUNTING FOR 9.2-INCH B. L. GUN, SHOWING THE 380-POUND SHOT IN THE LOADING TRAY READY FOR THE RAMMER

The greatest advance, however, has been made in connection with the machinery for elevating and training the gun and for conveying the ammunition from the magazine to the gun. While the minimizing of weight has, as in all the elements in warship design, been an important consideration, the primary aim has been to ensure reliability in operation, rapidity of fire even with high ballistics, and safety for the gun crew. The designer of gun machinery has first to ensure that the ammunition shall be brought from the magazines and shell rooms to a position in close proximity to the breech of the gun in readiness for the transference into

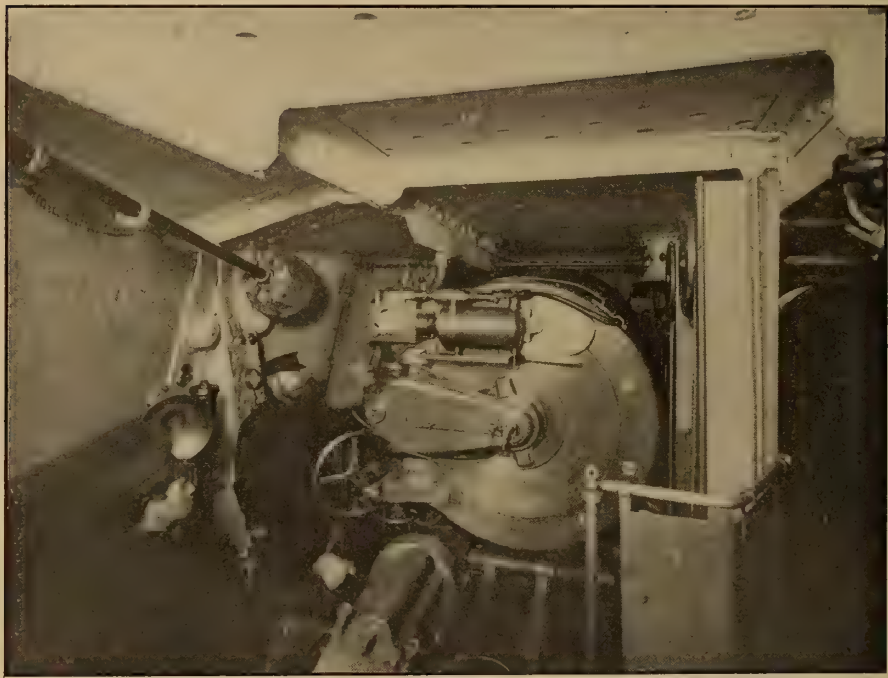
the chamber as quickly as possible and with the least risk of premature explosion. This has required the adoption of what is termed the two-stage loading system, a system in use ten years ago, but now much more universally adopted. The advantages have, in some navies, been tardily recognized; but an impetus was given by a disaster which overtook one or two foreign ships, due to premature explosion at the rear of the gun, causing flames to descend the hoist shaft and to involve danger in the magazines. The possibility of flames descending to the magazine is obviated by the two-stage loading system, as there is no shaft or opening from the gun platform to the magazine level. The projectile and powder charge are raised by hoists from the magazine to an intermediate position known as the working chamber, suspended to and rotating with the turntable, where the ammunition is transferred to independent hoists, which lift it to the loading position immediately to the rear of the gun. There is no need to enforce the advantage of this arrangement, especially as it has been established; greater rapidity is possible because of the shorter travel of the hoist used in the transfer of the ammunition from the working chamber to the gun and the consequently shorter period of time between the loading of the gun charge and the working of the cage to and from the intermediate stage with a second charge than would be the case if the cage had to descend to the lower level of the magazine. Moreover, projectiles can be stored in the working chamber, a point much nearer the gun than the magazine, thereby forming a ready emergency supply.



PEDESTAL MOUNTING FOR 7.5-INCH Q. F. GUN, SHOWING 200-POUND SHOT IN LOADING TRAY READY TO BE SWUNG ROUND IN LINE WITH THE CHAMBERS OF THE GUN

Another development conducive to rapidity is in the extended use of mechanism for loading the gun at any degrees of elevation or depression. To achieve this the rammer is mounted to the slide which carries

the gun and is elevated or depressed along with the gun. Formerly the gun in most cases had to be brought to a fixed position for loading, and although ten years ago there were several applications of mechanism for loading at any position, the system is now almost universally adopted, at all events within limited range of elevation or depression. There can be no doubt of the gain by the application of this system, although many authorities question the need for adopting it for maximum degrees of elevation. This hesitancy is the more pronounced as in some recent ships the guns are arranged to fire at as high an elevation as 35 degrees with 5 degrees depression, making 40 degrees in all. Normally, an elevation of 14 degrees or 15 degrees may suffice, as it represents a range of 18,000 yards with a modern 12-inch gun. In all mountings it is desirable to be able to load the guns at any angle within this range. It may be argued that 7 or 8 degrees suffice for ordinary ranges, say up to 12,000 yards; but we must now look for fighting at longer ranges, up to 18,000 yards. Moreover, heed must be paid to the possibility of the hull of the ship being so damaged as to give it an inclination, when to secure even horizontal fire the guns would require to be at an angle sufficient to counteract the heel of the ship.



BREECH OF GUN IN 12-INCH GUN HOUSE

Arrangement of mechanism for operating the breech-block. The breech is closed and the gun ready for fire. Below in the forefront is shown the hydraulic rammer, which is carried out on a support from the gun carriage.

Another necessity in ordnance design is to ensure that the gun layer can manipulate with ease the elevating and training gear. The transporting machinery in the shell rooms and magazine must be capable of rapid movements, and the methods for bringing ammunition from the cages in the trunk hoists must be

simple and expeditious, and necessitate only the minimum of fatigue to the crew while maintaining a continuous supply over a lengthy period. The hoist cages should have rapid movement alike in upward and downward travel, and the various devices of loading and unloading the cages should have interlocking gear to obviate any danger or check in the sequence of operations.

These desiderata in design involve the question of the choice between hydraulic and electric prime movers. Reliability is the first consideration; it is essential to obviate any chance of derangement by shock either by direct impact of armour-piercing shell or by the shattering effect of high-explosive shell bursting in the vicinity of the gun machinery. There is a tendency at the present time to favour the adoption of electric machinery; but when one reflects upon the high efficiency achieved by the hydraulic system there is justification for doubt as to a change, unless for thoroughly approved reasons. The Japanese guns during the recent war proved so reliable and justified British design, and particularly hydraulic mechanism, so fully that there is ground for any conservatism that may be displayed in retaining the water-power. Seldom has there been such pronounced trial in warfare as that to which the British-made guns were subjected throughout the recent war, and in every respect the machinery proved admirable.

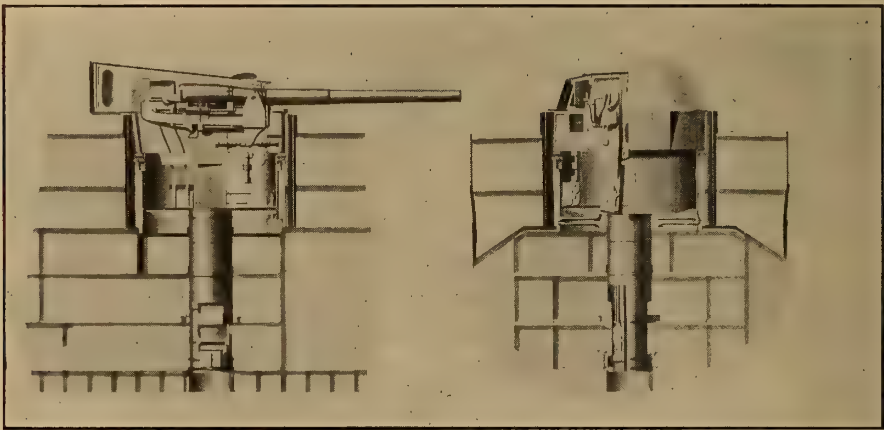
It is true British engineers have achieved very satisfactory results with electric machinery for working turrets; but there must be anxiety as to possibilities of anything going wrong with the electric circuit when in action, because it is so difficult to locate short circuiting—a danger which it is difficult to avoid—that might throw the whole of a twin gun mounting out of action. On the other hand, guns have been known to burst, with disastrous effects to the gun crew, without a single hydraulic pipe being broken. There is, further, a danger of fire from electric spark, and nothing is so serious in a region of high explosives as fire; but by judicious design this danger can be rendered very small. The direct action of hydraulic mechanism, too, is most convenient for many operations, as, for instance, the running out of the gun and the operation of the rammer. There are, however, other operations where the rotary motion of the electric engine is more applicable.

Electricity is often desirable as a standby, and then a relatively small application will suffice, as, notwithstanding the fact that a twin 12-inch gun mounting involves a rotating weight of over 450 tons, the load is beautifully balanced in every instance, and particularly on the roller path on which the mechanism rotates, so that a comparatively small power in the form of an electric auxiliary would suffice until the fractured hydraulic pipe or other derangement was remedied. As regards the complete failure of hydraulic supply, the pumps and most of the gear are almost invariably arranged in duplicate, and, in any case, excessive care is exercised to ensure reliability. It is in such questions that any effort at economy at all costs would be an unjustifiable blunder. The hydraulic pumps used, for instance, are of exceedingly high standard. Thus, gun-metal of very high quality is used for pump barrels and other working parts, especially where there would be possibility of deterioration were steel and iron used.

Having dealt with general conditions, we may now turn to a consideration of the mechanism which has been evolved as the result of much research and experiment, and by means of which such efficient results have been achieved. A general diagrammatic view of a modern 12-inch gun mounting is given in the illustration. Anyone who has had the opportunity of examining such machinery must have been impressed not only with the effort at reliability,

but with the limitations alike as regards space available and weight permissible. The ship designer very properly desires to reduce his displacement and justifiably imposes limitations. It is thus to the credit of the ordnance engineer that, whereas ten years ago the muzzle energy developed per ton of weight of gun mounting was only 327 foot-tons, it now approaches 550 foot-tons; so that, although the demands for efficiency in gun mountings has unavoidably increased the weight of a twin-gun turret mounting, the energy at the disposal of the fighting captain of the ship has increased at a much greater ratio.

It will be seen from the general views that, in accordance with latest practice, the guns are mounted on carriages supported in gun slides, which are provided with all the necessary fittings to control the movement of the gun backwards or forwards and the mechanism for ramming the projectiles and explosive charge into the chamber, as well as for opening and closing the breech by hydraulic power. Thus all of these operations can be discharged irrespective of the angle of training or of elevation of the gun. The slides are provided with trunnion bearings at the forward end, the trunnions being carried on suitable brackets on the upper floor of the turntable; and as the centre of gravity is as nearly as possible coincident with the centre of the trunnion, the minimum of power is required to elevate or depress the muzzle of the gun. The guns, their mountings and loading mechanism are thus carried on a turntable supported on roller bearings which travel on a circular path, in the manufacture of which excessive care is taken to ensure absolutely accurate surfaces.



SECTIONAL VIEW OF A MODERN 12-INCH GUN MOUNTING

Suspended under the turntable is a working chamber 9 or 10 feet in height, which forms the intermediate position in the two-stage loading system. From this chamber, extending through the turntable, there is a passage for raising the ammunition to the rear of the gun, while to the underside of the chamber is a trunk for the hoist cages raising the ammunition from the magazine floor to the intermediate stage. These trunks, as well as the working chamber, rotate with the gun. The rotating mechanism, which usually is of the hydraulic type, is supported on the bottom plating of the turntable and, therefore, in the working chamber, so that the operator within it has under continuous observation this hydraulic mechanism. This turning gear, however, is actuated through

valves under the control of the gun captain. The connection between the hydraulic pumps, which are arranged in the ship independently of the mounting, is through walking pipes with swivel joints, and from these pipes the pressure water is delivered to the various machines in the turret. The hydraulic motors transmit their power through suitable gearing to the training pinions gearing, with a continuous rack fitted to the structure carrying the turret.

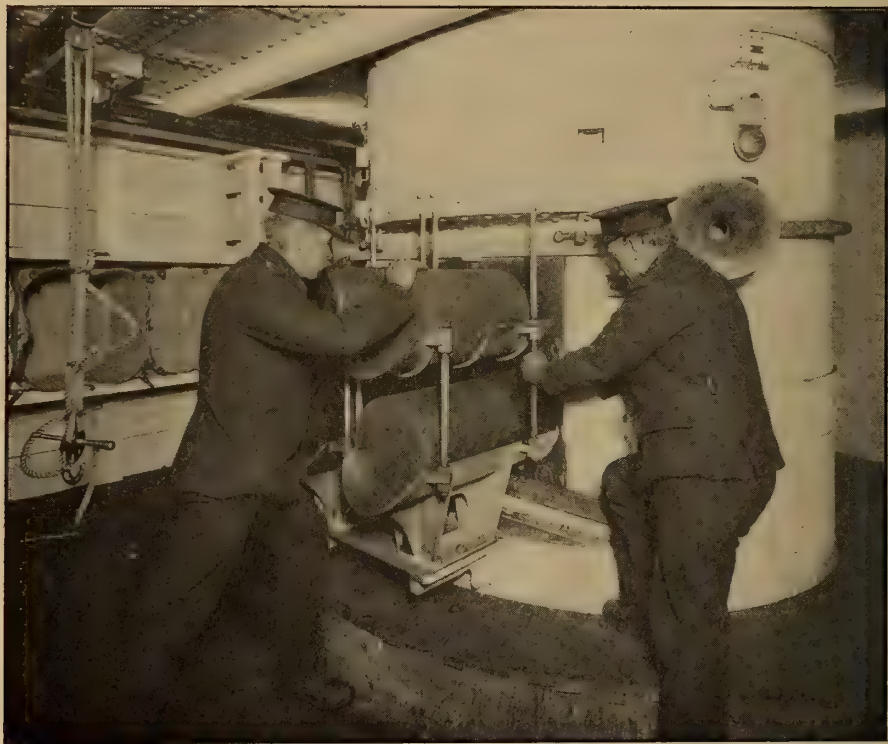
The mounting, which is shown in the general drawing, is further interesting, as it illustrates the method of applying electric power for auxiliary or emergency use in training the gun. In this case the power is transmitted from the motor to the training shafts or pinions, also operated by hydraulic gear, by means of a special form of apparatus known as the "Janney transmitter," which has immense potentialities not only for such systems, but for many cases where precision of control is desired in combination with great variations in the rate of revolution. In this controller a body of fluid is employed to transmit the power from the motor to the shaft or mechanism to be driven. With this transmitter the motor runs at a constant speed and in the same direction—desiderata for efficiency in all electric motors—and no reversing of the motor is required to obtain a change in the direction of motion in the shaft or mechanism to which power is transmitted. The "Janney transmitter," by the simple movement of a lever, reverses the direction almost instantly, notwithstanding very high speed of rotation either on the part of the motor on the one hand or of the motion shaft on the other. This controller has been applied not only for the training of guns in the American Navy, giving splendid re-

LOWER END OF ROTATING TRUNK.—LOADING THE SHELL CAGES

The operator at the side is shown at the levers for controlling the lifting grab and transporting runner on the overhead rail.

sults, but in various other directions; and more is sure to be heard of it in the near future in general applications.

The charge is hoisted through the trunk to the intermediate or working chamber from the shell room, which is contiguous to the base of the trunk. The projectiles are transferred from the bin where they are stowed along overhead transporting rails by power-worked runners, one of which can be seen in the centre of the illustration. This runner has a special form of grab, which, as it is lowered, encompasses the body of the projectile. As it is raised again by a small hydraulic cylinder the jaws close around the projectile. The operator is shown at the levers controlling the lifting grab and the hydraulic presses used for traversing the runner. The projectile is deposited from the runner onto a tray fixed on the floor of the chamber, and from this it is rolled onto a bogie, which is rotated around the rack fixed to the base of the trunk. This enables the bogie to be moved to suit the position of the door communicating with the cage while the trunk and cage are rotating along with the whole of the turret machinery. There is interlocking gear between the cage and the door of the hoist, so that until the cage is in position behind the door the latter cannot be opened, nor can the projectile be moved through the doors until the cage is in a position to receive it.



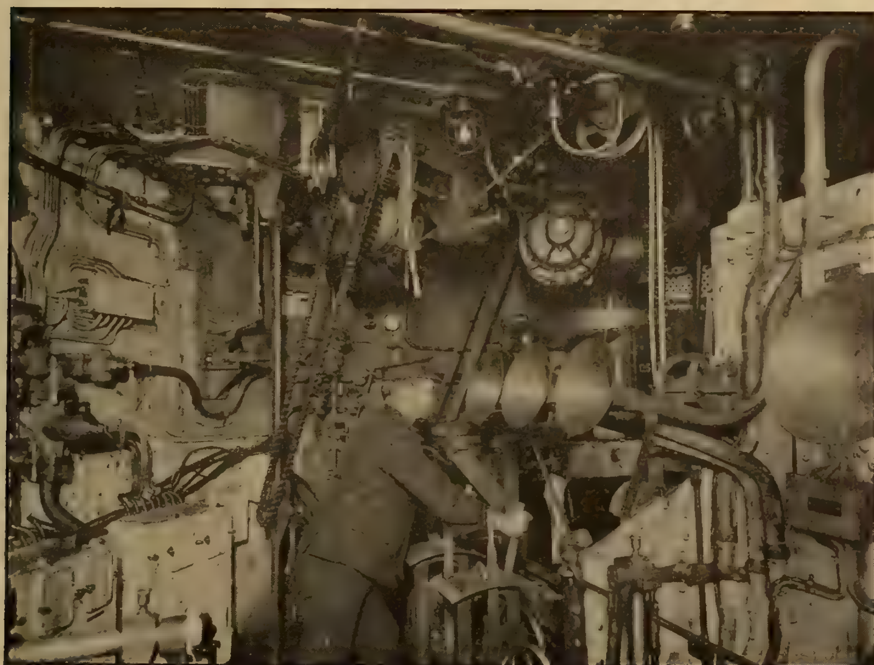
ROTATING TRUNK IN HANDLING ROOM

Loading the powder charges into the ammunition cage; showing the trays on which the charges are placed in readiness to be transferred to the lifting cage.

The powder charges are arranged to be loaded in cages at the magazine floor, which is, as a rule, im-

mediately over the projectile room. The weight is such that it can be easily handled. The charges are placed in suitable receptacles attached to the trunk in readiness to be transferred to the lifting cage as the latter comes into position for loading. Interlocking gear is here also provided on the doors, to ensure that the ammunition shall not be passed into the trunk until the cage is in a proper position to receive it.

Independent ammunition - loading hoists are arranged where there are two guns in a turret, and all cages are operated from the working chamber. This applies not only to the hoist from the ammunition floor to the working chamber, but also to those from the working chamber to the rear of the gun. In the view of the interior of the working chamber the operator is shown at the handle for manipulating these hoists. Incidentally, it may be stated that dials are provided, so that the operator can at once see the position of the cages. The gear is all interlocked, so that there is no possibility of premature hoisting or loading or of jamming. The illustration gives an idea of the extent of machinery adopted. It suggests complications; but to the expert everything is simple, and experience has proved the reliability as well as the impossibility of confusion.

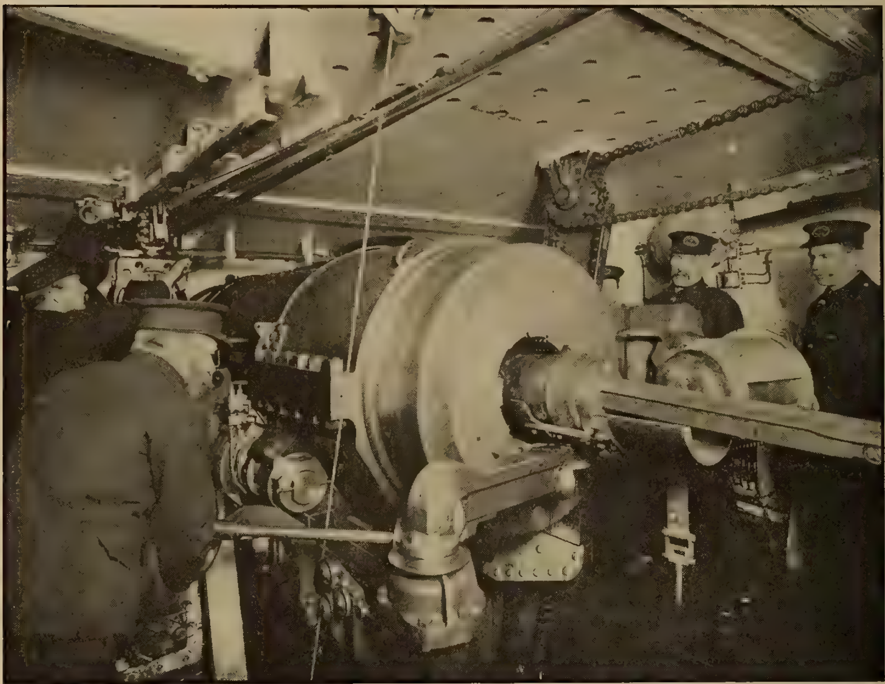


INTERIOR OF WORKING CHAMBER

View showing a portion of the gear required in connection with the working of the ammunition. The operator in the illustration is shown at the levers for raising and lowering the ammunition hoists in the trunk, and for controlling the hoists leading to the guns.

The cages at the end of their travel into the turret are guided on curved rails concentric at the upper ends with the gun trunnions. Thus, at the end of the travel the projectile comes into direct line with the chamber of the gun, irrespective of the angle of training or of elevation. The rammer is thus easily brought into contact with the base of the

projectile, while the point is immediately opposite to the breech opening. The rammer now usually adopted is of the flexible-chain type. It is in the form of a series of links, which can be coiled up, although in one direction only. It thus occupies much less space. The links of the chain are so formed that, when extended by means of the hydraulic motor, the abutments of the link keep the chain rigid and prevent any sag beyond the predetermined amount. On winding the rammer back from the gun after the charge has been driven home, the links are automatically turned and form a flexible chain for convenience in stowing the gun slide. The method of operating the rammer is very simple, the motor having three cylinders operating one crank. Mounted on the crankshaft is a pinion which gears into a bevel wheel on the chain sprocket shaft. By the rotating of this shaft the links are sent forward in succession over the sprocket wheel, and, by reason of their formation, retain a rigid position, so that they drive the projectile home into the chamber of the gun. Interlocking gear is fitted so that the motor valve cannot be operated unless the cage, with its projectile, is in the correct position behind the gun for ramming the projectile home. Similarly, the cage cannot be lowered until the rammer is housed.



BREECH END OF GUN IN 10-INCH GUN HOUSE, SHOWING THE LOADING TRAY AND THE OPERATIONS OF RAMMING THE PROJECTILE INTO THE GUN

After the projectile has been driven home, the powder charge is transferred from the cage onto the tray which previously carried the projectile, and from thence it is driven into the gun in a manner exactly corresponding to that adopted for the projectiles, and the breech is then closed.

Even when being loaded the gun can be elevated and trained at the will of the captain. This, of course, is a result of mounting the loading

gear on the gun slide, which moves with the gun either in the vertical or horizontal plane. The advantages of this are incalculable, as, independent of any operation within the turret, the gun captain can keep his sights on the objective and thus be ready to fire when the gun has been loaded. The hydraulic presses for elevating or depressing the gun are secured to the turntable below

can also be used for running the gun in when necessary.

Three sighting positions are usually provided. At the centre position between the guns there are two sights, one for each gun. At the side positions there is only one sight for the adjacent gun. The training and elevating of the gun are, of course, under complete control from this position.

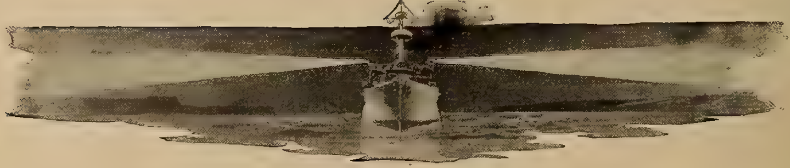
PEDESTAL MOUNTING FOR 4.7-INCH Q. F. NAVAL GUN USED IN FIELD OPERATIONS

each gun, as shown in the general arrangement of the mounting. The elevating press is arranged to traverse a crosshead connected by means of links to a bracket or arm attached to the inside of the slide frame in the front. Break cylinders are fitted for absorbing the energy of recoil, and hydraulic presses are provided within the frame of the gun slide for running the gun out to the firing position after fire. These same presses

From first to last the ultimate efficiency in naval ordnance is dependent upon the proficiency of the captain of the gun crew. The most expert mechanic may labour in vain, and the finest appliances that engineering can conceive will be futile, unless the man behind the gun is efficient. It is, therefore, of greatest satisfaction to everyone associated with the *materiel* of the navy, and particularly to the manufacturer of ordnance ma-

chinery, to realize that so much has been done to infuse into the personnel of the navy the ambition to excel in accuracy as well as rapidity of fire. A vast improvement has been made within recent years, and while every officer of flag rank must be commended for the development of the spirit of emulation and enthusiasm in this important work of naval efficiency, none will grudge a special meed of praise to Sir John Fisher, the present Board of the Admiralty, and to Sir Percy Scott and those who have been associated with him in the Naval Ordnance Department of the fleet. Splendid service has been done in the evolution of the modern sighting appliances and everything which tends to permit of accurate firing at long ranges. The percentage of possible error is reduced to the minimum by the modern range-finders and transmitters and other gear securing the necessary accuracy. Thus there has been made possible a high degree of accuracy which the men have been encouraged to achieve.

Of this increased accuracy convincing evidence is afforded by the annual returns of practice firing in the navy. In the case of the larger guns of 10-inch and 12-inch calibre, the accuracy is three times greater than it was ten years ago. The average for the whole fleet is now 0.61 hits per minute per gun, as compared with 0.23 under the conditions then prevailing. In the case of the 9.2-inch gun, the improvement is equally marked, being 3.25 hits per minute, as against 0.32. In the 6-inch, quick-firing gun, the gain is nearly six-fold, from 1.11 hits to 5.93 hits per minute. These, it must be remembered, are the average results for the whole fleet. When one considers the maximum results — and, therefore, the degree of accuracy— which may be achieved by perfection of mechanism and efficiency in personnel, the gain is still more remarkable. With the 12-inch gun, two hits per minute, and with the 9.2-inch gun four hits per minute, have been achieved, notwithstanding that now the conditions of firing are more severe.



THE INFLUENCE OF THE DEPTH OF WATER ON SPEED

By A. F. Yarrow, LL. D., M. I. C. E., and W. W. Marriner, M. I. N. A.

SOME recent trials with high-speed vessels have again brought forward in such a striking manner the influence of the depth of water on speed that it may be of interest to give a short account of some features of what is known about the subject, without going too deeply into the theories which have been advanced to explain the results of observation.

It has long been known to naval architects that the depth of water in which a trial is made has a considerable influence on the result obtained, and up to recent years it was believed that an increased depth was always attended with increased speed. Among the early published accounts of any reliable experiments should be mentioned those given by Captain Rasmussen, of the Royal Danish Navy, who gave in "Engineering," of September 7, 1894, the results of some trials he had made with a Danish torpedo boat running in shallow water, and in 1899 he read a paper on this subject before the Institution of Naval Architects.

About the same time, Major Rota, the well-known naval architect and engineer of the Italian Navy, made some experiments with models in a tank at Spezzia, and by varying the depth of water in the tank he obtained some remarkable curves giving the variations of resistance at different depths, and the results of these experiments he presented to the Institution of Naval Architects in a paper read in 1900.

A great deal of valuable work has been done in this field of investigation by other scientific men, amongst whom may be mentioned particularly Sir William White, Naval Constructor Paulus, of the Imperial German Navy; Herr S. Popper, of Pola; Mr. D. W. Taylor, of the United States Navy; and Messrs. Denny, and several interesting papers have been published on the subject.

As is well known, in very deep water the resistance varies in a fairly constant ratio of some power of the speed, and the curve connecting speed and horse-power is a smooth one, and it was pointed out very many years ago by Sir W. White, in his standard work on "Naval Architects," that the influence of the depth of water is immaterial for the speeds then attained, if the depth exceeds 100 feet.

Mr. D. W. Taylor, of U. S. N., in his work on "Resistance of Ships and Screw Propulsion," gives the following table of depths, beyond which increase in depth has no effect on the resistance of any particular speed:

Speed of Ship in Knots.	Depth at which Resistance is Normal.
10	28
12	40
14	55
16	71
18	90
20	111
22	135
24	160
26	188
28	218
30	250

It might, however, fairly be said that the extreme importance of the effect of shallow water was not realized until it was brought home to the various contractors for high-speed vessels by the difficulty they experienced in obtaining the contract speed with the River-class destroyers.

It will be remembered that these vessels were ordered by the British Admiralty, in 1902, and that they were of quite a new type, having a raised forecastle, and being of much heavier scantlings than any destroyers previously built.

Fig. 1 is a photograph of H. M. S. *Garry*, the fastest vessel of this class.

These vessels had a contract speed of 25½ knots, and a displacement on trial which varied from 550 to 600 tons, and it was estimated that there would be no difficulty in obtaining this result.

might be expected, with increasing speed, up to about 23 knots, but above this speed the horse-power required for any further increase was quite abnormal.

At the same time, it was found that similar vessels tried in deep water on the Skelmorlie mile at the mouth of the Clyde did not show this abnormal increase in horse-power at the higher speeds, the result obtained on this deep mile being evidently the true measure of the performance of the vessel.

As the vessels tried on the Thames

FIG. 1.—H. M. S. GARRY, BUILT BY YARROW & CO.

When the trials were commenced, it was found that the horse-power needed was much more than was contemplated, especially with the vessels tried on the Thames and on the East Coast.

A long series of progressive trials was therefore made by our firm on the measured mile at the mouth of the Thames, for the purpose of finding out if there was any special reason for this discrepancy, and curves were plotted to show how the horse-power varied with the speed. These curves showed that, with the vessels tried at the mouth of the Thames, the horse-power increased, as

were so nearly identical with those tried on the Clyde, we had to look to the depth of the water as being a serious disturbing element in the resistance at these speeds, and we were so convinced that this was the case that we erected a measured mile on the cliffs close to Dover where the depth of water available was about 30 feet more than on the Thames. This depth, which varied from 70 to 100 feet, was not the most suitable for the speed required, but it was chosen partly because it was somewhat sheltered, but mainly because of its proximity to some deep water, about 160 feet, just outside the Good-

FIG. 2.—EXPERIMENTAL TANK AT BREMERHAVEN

FIG. 2A.—VIEW UNDER TRAVELING BRIDGE OF THE BREMERHAVEN TESTING TANK

win Sands, where the greater portion of the trial could be run, and where the resistance would be normal.

After this mile had been carefully checked over for length by the Hydrographical Department of the Admiralty, we ran there the trials of the first four of the River-class destroyers, built by our firm, and the deep water enabled the contemplated result to be obtained.

purpose of further investigation, which they kindly consented to do.

Fig. 2 is a photograph of the experimental tank at Bremerhaven.

Fig. 2a is a photograph showing the underside of the towing carriage and the model being towed.

Fig. 2b is a photograph of the paraffin model being cut to shape in the special copying machine.

An exact model of the destroyers

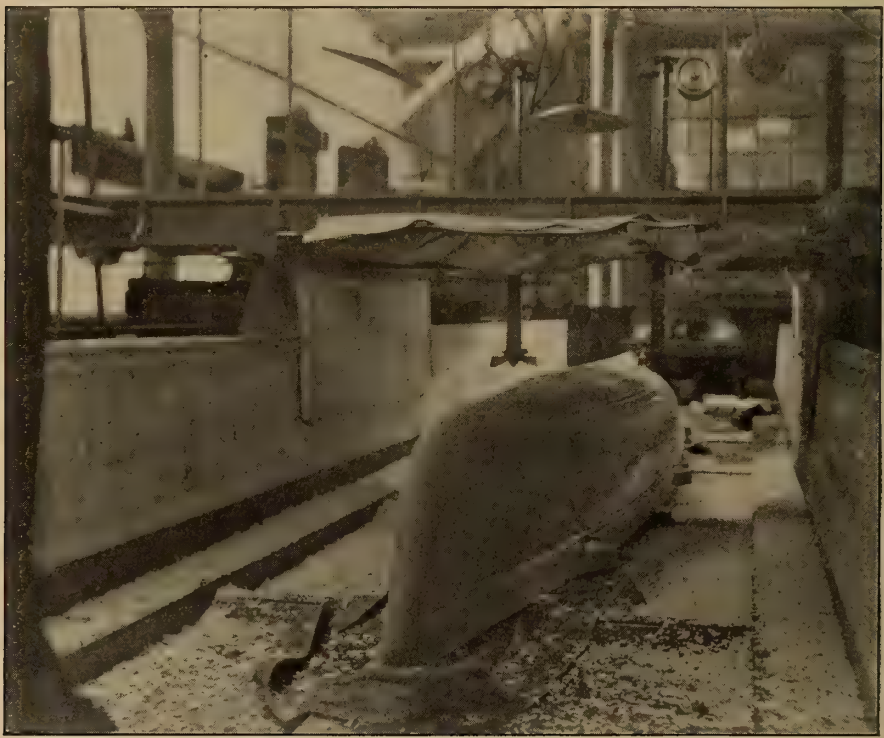


FIG. 2B.—CUTTING A MODEL HULL FOR USE IN THE TESTING TANK

in question was made, and the resistance of the model when loaded to correspond to 600 tons displacement was tested also when loaded to 450 tons at various depths of water. The depths were made to correspond to depths of from 20 to 90 feet. The results of these experiments are given in Fig. 3. It will at once be seen from a study of these curves that there is a distinct hump in each, where for a small increase in speed there is a great increase in power;

It must be borne in mind that the contract speed had been calculated on the supposition that the resistance would be the normal resistance, and not one depending on the depth of water.

To investigate this important subject still further, and as there was unfortunately not a public tank available in this country where model experiments could be made, the North German Lloyd were asked to lend their tank at Bremerhaven for the

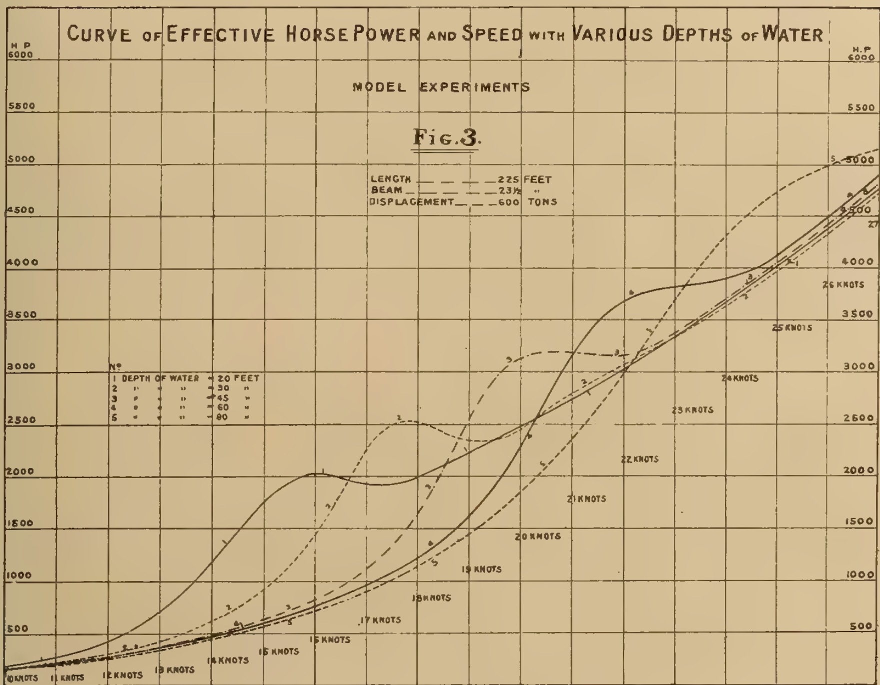


FIG. 3.—SPEED-POWER CURVES

and also it will be noticed that the hump occurs at higher speeds as the depth of water increases.

This hump in the curve is so marked in many cases that it shows the interesting fact of two very different speeds having the same resistance; for instance, it takes the same power for a speed of 20 knots as it does for 22 knots when the depth of water is 45 feet.

Under ordinary conditions, in deep water we should have expected this higher speed of 22 knots to have re-

FIG. 4.—AUSTRIAN TORPEDO-BOAT DESTROYER HUSZAR. SPEED, 28.537 KNOTS. YARROW & CO., LTD.

quired 20 per cent. more power than the lower speed.

These experiments with models showed so plainly the direction in which we might look for a solution of the problem of shallow-water resistance, that it was determined to make a more complete set of experiments with a full-size torpedo-boat destroyer, and a series of progressive trials was carried out on a special course at the mouth of the Thames, the depth of water along the course having been accurately measured just before the trials. Fig. 4 is a photograph of the destroyer with which the experiments were made.

The results of these experiments were placed before the Institution of Naval Architects in the spring, 1905. In Fig. 5 is given one of the many instructive diagrams which were shown, and it will be seen that the experiments with a full-sized destroyer give exactly the same shape of curve as was obtained in the model experiments. For instance, when running in a depth of 40 feet, the model experiments give the hump in the curve of the resistance to occur at about 20 knots, and the experiments with the destroyer give the hump at practically the same speed.

As a result of these experiments and from the data made available by other investigators, it was found that the depth in feet to be avoided is approximately represented by

$$\frac{(\text{speed in knots})^2}{10}$$

The speed at which the hump occurs in the resistance curve at any particular depth is sometimes called the "critical combination" of speed and depth.

Fig. 6 shows a curve giving the combinations of speed and depth

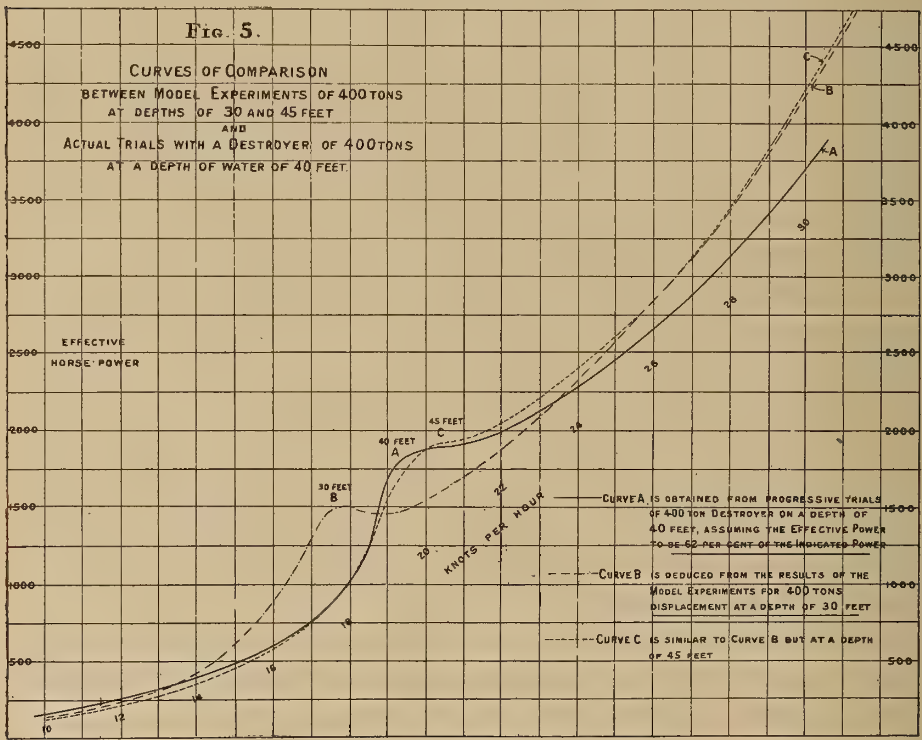


FIG. 5.—SPEED-TRIAL CURVES AT VARIOUS DEPTHS

where the resistance is abnormal, or, in other words, the depth to be avoided at any given speed.

There can be no doubt that in order to get the correct performance of a vessel, it is necessary to run the trials in deep water—deep water being the depth beyond which the result obtained would be constant—and the above-mentioned experiments with models and with full-size destroyers confirm this statement in a marked manner.

the same speed as the ship, otherwise they would either run away ahead or be left astern, which is not the case as long as the vessel is running at constant speed.

Now, the peculiar wave formation which has such an influence on the resistance when running in shallow water is dependent on the speed translation of the waves over the bottom. That is to say, the wave formation in shallow water is dependent on the speed of the ship over

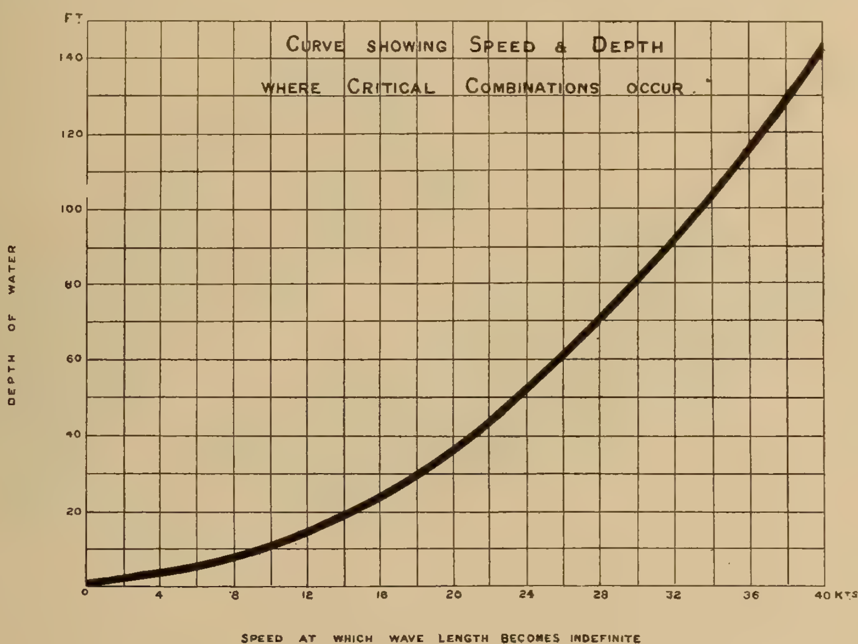


FIG. 6.—CRITICAL-SPEED CURVE

It might be of interest to mention some of the peculiar difficulties that are met with in carrying out these experiments on the effect of shallow water.

One of the most important is the influence of the tide. When running in a tide way, or in a river, in order to obtain the speed of the vessel through the water it is necessary to make a series of runs with, and against, the stream.

It is evident that the waves accompanying a vessel must travel at the bottom, rather than on the speed through the water, which latter we always consider as the speed of the ship in any calculations.

For instance, suppose we wished to make an experiment with a vessel running at 25 knots in water 60 feet deep, and the tide at the same time was running at 3 knots.

When going against the tide the speed over the bottom would be 22 knots, and, consequently, the wave formation would have the characteristics of 22 knot waves in 60 feet of

water. On the other hand, when going with the tide, the speed over the bottom would be 28 knots, and the wave formation would be that of 28-knot waves in 60 feet of water, so that although the speed of the vessel was 25 knots through the water, the effect on the resistance due to the shallow water would be that due to speed of either 22 knots or 28 knots.

Another difficulty is the variation in the depth due to the tide rising or falling while the experiment is being made. And again the hump on the curve of resistance is so pronounced that while ascending the hump it requires an enormous increase of power for a small gain in speed. On the other hand, after passing the hump the speed is rapidly increased for a small increase in power, as in the case already referred to—of its taking the same power to drive a vessel at 22 knots as it did at 20 knots in 45 feet of water—and it will be readily understood that when making an experiment it is not easy to run at any required speed near the hump of the curve.

Owing to these peculiar difficulties, over and above the ordinary incidents of trial trips, it will at once be seen that to obtain accurate data was a long and tedious process.

As all observations point to the fact that the abnormal hump in the resistance curve is caused by an increase in the wave-making resistance, due to the wave formation being more or less modified in shallow water, it follows that another very important consideration is the effect of the interference of the bow system of waves on the waves formed by the stern, but we will not consider this portion of the subject further than to draw attention to Fig. 7, which is Froude's picture of the waves formed by a ship in its passage through the water, showing how the transverse wave formed at the bow is repeated at intervals along the ship, and when the bow wave gets to the stern it will either help to increase the waves at the stern or tend to make them smaller, according as to whether or not they are in step with them. It is this interference of the bow and the stern waves which make for every vessel one combination of depth and speed much worse than any other.

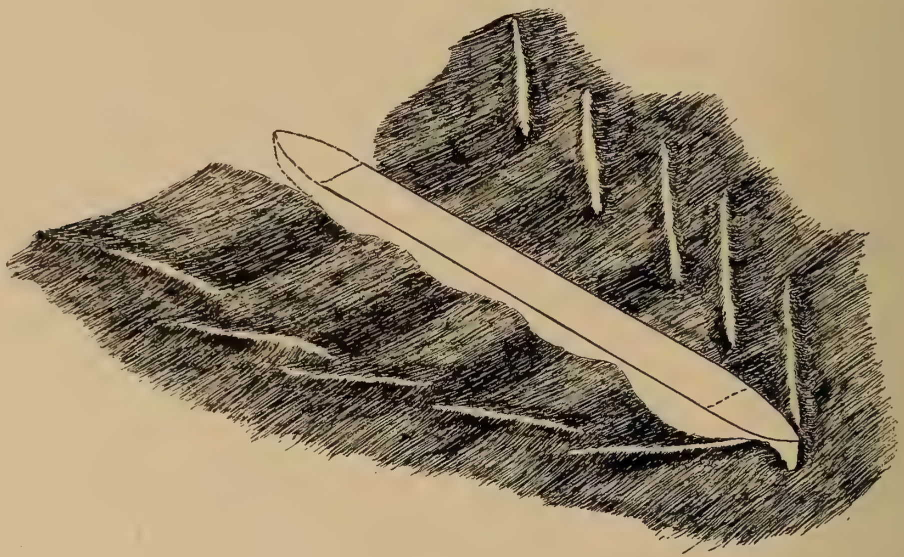


FIG. 7.—FROUDE'S PICTURE OF THE WAVES FORMED BY A SHIP IN ITS PASSAGE THROUGH THE WATER

The equation already given of the

depth to be avoided being approximately

$$\frac{(\text{Speed in knots})^2}{10}$$

refers only to the transverse waves formed by a ship, but there is no doubt that at very high speeds the effects of the diverging waves cannot be neglected.

These diverging waves have a speed less than the speed of the ship, their speed being equal to the component of the speed of the ship in the direction of the propagation of the diverging wave.

The position of the point of maximum interest of resistance is fairly well defined on the curves, but the question of minimum resistance is not so readily answered; that is to say, what depth will give the least resistance for any given speed is a more difficult problem.

If we closely examine the results obtained by the various investigations there is evidence that the resistance curves in very shallow water fall below the normal, and Mr. S. W. Barnaby, in the Watt anniversary lecture of 1906 on marine propulsion, gave the result of his study of this question of minimum resistance, which is of great professional value.

It should be pointed out that the depth of water on the Maplin mile is dependent upon the distance from the shore where the trial is made, which fact is often disregarded.

It is quite possible that when once the depth for maximum resistance is passed, any reduction in depth is an advantage by reducing the resistance.

The resistance curve at any given

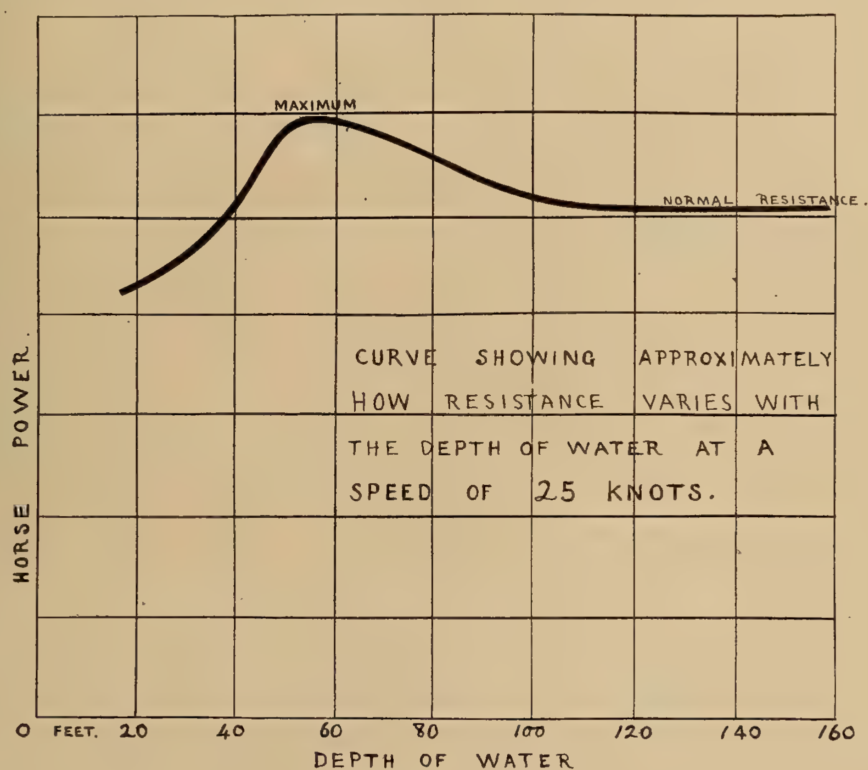


FIG. 8.—SPEED-RESISTANCE CURVE

speed for varying depths will probably be somewhat like that shown on Fig. 8, so that if we try a vessel under conditions of speed and depth represented by a spot well to the left of the curve, in Fig. 6, we shall obtain an increased speed, due to the resistance being below the normal.

For instance, if we were to run a vessel at 32 knots in a depth of 60 feet, we should obtain the speed with much less horse-power than if the vessel were run in water of, say, 200 feet, or greater depth; and we should get an even better result in 40 feet depth; or, in other words, with the same horse-power in this vessel we should obtain a speed in water 40 feet about a knot or so better than in deep water.

To obtain reliable results of the performances of different vessels, whether of the same class or of different classes, it is essential that the trials be made in a depth of water beyond which the result would be constant, however much deeper the water may be. Having in view the present high speeds obtainable, there are a very limited number of places where such trials can be made, especially as they must take place not far from the shore, in order to make the necessary observations. Round the coast of Great Britain it seems very doubtful whether there is another measured mile besides the one at the mouth of the Clyde that can conform to the necessary conditions while at the same time it is sheltered so as to enable the trials to be made with safety.

GAS ENGINE EXPERIMENTS IN H. M. S. RATTLER

By The Marquis of Graham

MUCH lately has been heard of the possibilities of suction gas for purposes of marine propulsion; but there is a dearth of fact, or actual experience for judgment, to go upon. The only instance in the United Kingdom of suction gas being practically used for driving a ship is the installation of a 500-horse-power plant in the gunboat *Rattler*, of the Clyde division, Royal Naval Volunteer Reserve. Hence the data obtained from the performance of this ship constitute the only valuable experience yet available for naval architects, ship owners and engineers to study.

As the *Rattler* is the seagoing training ship of the Volunteers, and therefore cruised only at week-ends, it has not been possible to carry out experimental work purely from an engineering point of view, or perhaps as exhaustively as might have been done had there been only scientific purposes to serve. Nevertheless, Mr. Andrew May, engineer to Messrs. William Beardmore & Co., Dalmuir, has expressed himself well pleased with the results attained, and the great amount of information learned on the various trips.

H. M. S. *Rattler* is one of the old British gunboats, lent to the Clyde division, R. N. V. R. Her description is as follows: Composite construction; single screw; length, 165 feet; beam, 29 feet; mean draught, 11 feet 2 inches; displacement, 715 tons; indicated horse-power (forced draught), 1,000 = 13 knots; natural draught, 600 = 11.5 knots. The ship was launched at Elswick, Oct. 8, 1886. Her old steam engines, boilers, etc., have been removed, and a single set of vertical Beardmore-Captaine suction-gas engines and producer installed in their place. As regards the technical construction of the engine and its working, these could not be better described than by the pen of Mr. Andrew May, under whose personal supervision the engine was constructed and the alterations carried out:

The machinery of H. M. S. *Rattler* consists of a 5-cylinder, single-acting suction gas engine and producer of 500 brake horse-power, the cylinders being 20 inches diameter by 24-inch stroke, revolutions 120 per minute. This engine, owing to its special construction, can be considered the most suitable type of internal-combustion engine of large power for marine work. The engine frame is built of steel plates and angles, thus giving a very strong and rigid machine with a minimum of weight, cast iron being only used for the cylinders and cylinder heads. Each of the five cylinders is independent of the others, so that if desired one engine may be shut off and valves, etc., examined while the four remaining cylinders are working. A magneto is fitted to each cylinder, the ignition being of the low-tension make-and-break type. This type of ignition is especially adapted for marine work where so much moisture is met with, which can do serious harm where there are high-tension leads. During the whole commission of H. M. S. *Rattler*, both this year and last year, the ignition has been unfailing. Forced lubrication is used for the cylinders, and the engine being of the open type, the main bearings, bottom ends and gudgeon pins are lubricated by hand.

The gas generator of the usual type for using anthracite coal is a steel shell lined with firebrick and provided with a feeding hopper on the cover, this cover being water cooled. The fire-bars are trough-shaped and placed radially around the producer. The inner ends are supported on a tube; water is kept circulating through this tube and so prevents the burning away of the edges of the fire-bars.

The cleaning plant is comprised of cooling tower, centrifugal drier and cleaner, and these occupy very little space.

The gas, after leaving the producer, enters the bottom of the cooling tower and leaves at the top. The gas in its upward course comes in contact with water sprays and is thus cooled and cleared of any grit that may be in it. After leaving the cooling tower, the gas passes to the centrifugal drier in which the fan is revolving at a high rate of speed, and any water that is in the gas is thrown off to walls of the casing and drained therefrom to a water seal. The gas being lighter remains at the centre of the fan and is then drawn through the cleaner to the mixing valve on the engine and thence to the various cylinders. The cleaner is a square box filled with perforated plates, packed closely together. The gas enters at the bottom and rises diagonally to the top, and on its passage impinges against the plates and thus removes any dirt or water that perchance may still be in the gas. The plates in the cleaner are perforated in a special manner to give the best desired result.

H. M. S. RATTLER BEFORE SHE WAS FITTED WITH GAS ENGINES

The exhaust, after leaving the cylinders (the exhaust valves and inlet valves are water cooled), passes through casings which may be termed boilers. These effectively silence the exhaust. These casings or boilers contain a nest of tubes through which water is circulated, and the hot exhaust passing around them generates the steam that is used in the producer.

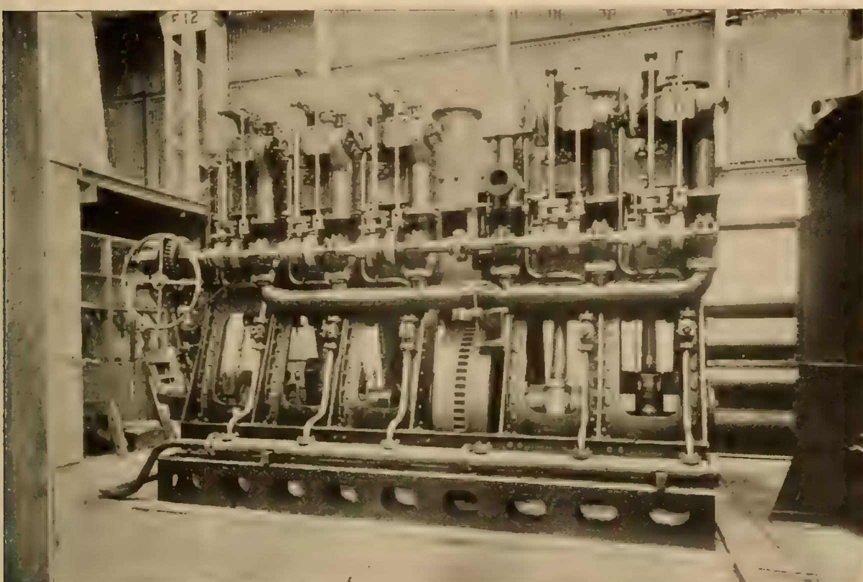
Reversing is effected by means of a hydraulic clutch working through an epicyclic train of wheels. The

engine is started by means of a mixture of gas and air pumped up to a pressure of 95 pounds per square inch, which is admitted to the cylinders through a specially constructed valve and then fired. This compressed mixture can be used with perfect safety without any fear of back-firing, as the mixture cannot be fired until the admission valve is closed. The engine invariably starts up with the first impulse and gets sufficient way on to draw in the gas from the main mixture pipe; then by this time the starting mixture valves and tappets have been automatically closed and thrown out of gear by the governor.

A marine gas installation should appeal to those engineers who have had the worries of priming boilers, tubes giving out, furnace crowns coming down, and the hundred and one other things in the stokehold that go to make the sailing engineer's life a burden. With the advent of the marine gas engine, the stokehold may be said to have been eliminated.

In regard to the actual performance of the vessel, the *Rattler* has run, up to date, 1,800 miles; and it is well within the mark to say the average speed attained has been 8 to 9 knots. Under natural draught as a steam vessel, the *Rattler* did not run at greater speed, and under forced draught the records of her performances, if ever they existed, are lost in antiquity.

This being the first effort to work a ship by gas, no attempt was made to drive at great speed. Reliability in, and control of, engines was the first consideration, especially so as no one knew how the machinery would perform under varying load and conditions. Every possible kind of weather has been experienced. The severe gales of autumn have shown beyond doubt that "a good jacketing" agrees with the gas engine, as also a long, continuous run. With a pitching, or rolling, gas ship, the discomforts of a steamer's stokehold are non-existent. There is no shoveling of coal in a dark, grimy and confined space. The feeding of



ENGINES OF H. M. S. RATTLER

a gas producer is intermittent, and can be done automatically instead of by hand. The heat of a producer room is nothing in comparison with a stokehold, and, by reason of its arrangement, it can be ventilated far better. In fact there need be no covering between the floor of the producer room and the open hatch.

In the matter of space and weight, the gas and producer installations save about 25 per cent. to 30 per cent on the corresponding items of a steamer's outfit. But it is in the cost of labour and fuel that the chief benefits are to be found.

H. M. S. *Rattler*—as a steamship—had an engine room and stokehold complement of seventeen hands, being four engineers and thirteen stokers. As a gas ship, she runs easily with a complement of seven, being three engineers and four producer attendants; but the functions of the latter can easily be done by seamen, since attendance on the producer entails but a few minutes' work every two hours.

In the matter of fuel, the *Rattler* experiments have proved most enlightening. The ship has been run on Scotch anthracite coal, costing 15*s* 6*d* per ton, and this gives quite as good results as could be obtained under steam running on the more costly best Welsh product. Furthermore, the experiments have brought to knowledge a means by which suitable gas can be obtained from the commonest of coals—even that known as dross, at five or six shillings a ton. Developments have been planned for simplifying the engine considerably and still further reducing its weight. A great claim to be appreciated will be the fact that twin-screw engines can be fed from one and the same producer, thereby eliminating necessity to greatly enlarge the producer room, or double the number of fires.

Gas is extremely handy as a power to get under weigh, or come to anchor with. From "all cold," the *Rattler* can start in 30 minutes. From keeping the coal just aglow, 15 minutes; and from ringing "Finished with engines," all hands can be clear of engine room and producer hold in 10 minutes, their work being absolutely finished.

The gas engine most strongly favours the interests of a cargo vessel. While moderate in speed, it possesses great reliability and quite certain economy. The consumption of fuel is about 50 per cent. of that which would be consumed on a similarly powered steam vessel: hence the "radius of action" of the ship is about 100 per cent. increased. Wherever steamships can run, gas ships can go. It requires but small experience to be convinced that the mercantile marine is about to witness a great revolution in propulsion.

RECENT DEVELOPMENTS IN THE MARINE STEAM TURBINE

By R. J. Walker

WITHIN the last few years many papers have been read and numerous text-books published dealing with the steam turbine engine and its several applications, and there would appear very little to add, either from a scientific or a practical point of view. The writer ventures to hope, however, that, in view of the rapid development of this type of engine as applied to the propulsion of ships, a short review of its growth, with recent developments in design, may not be without interest.

With one or two exceptions, to which reference will be made later, all marine turbines so far have been of the Parsons type.

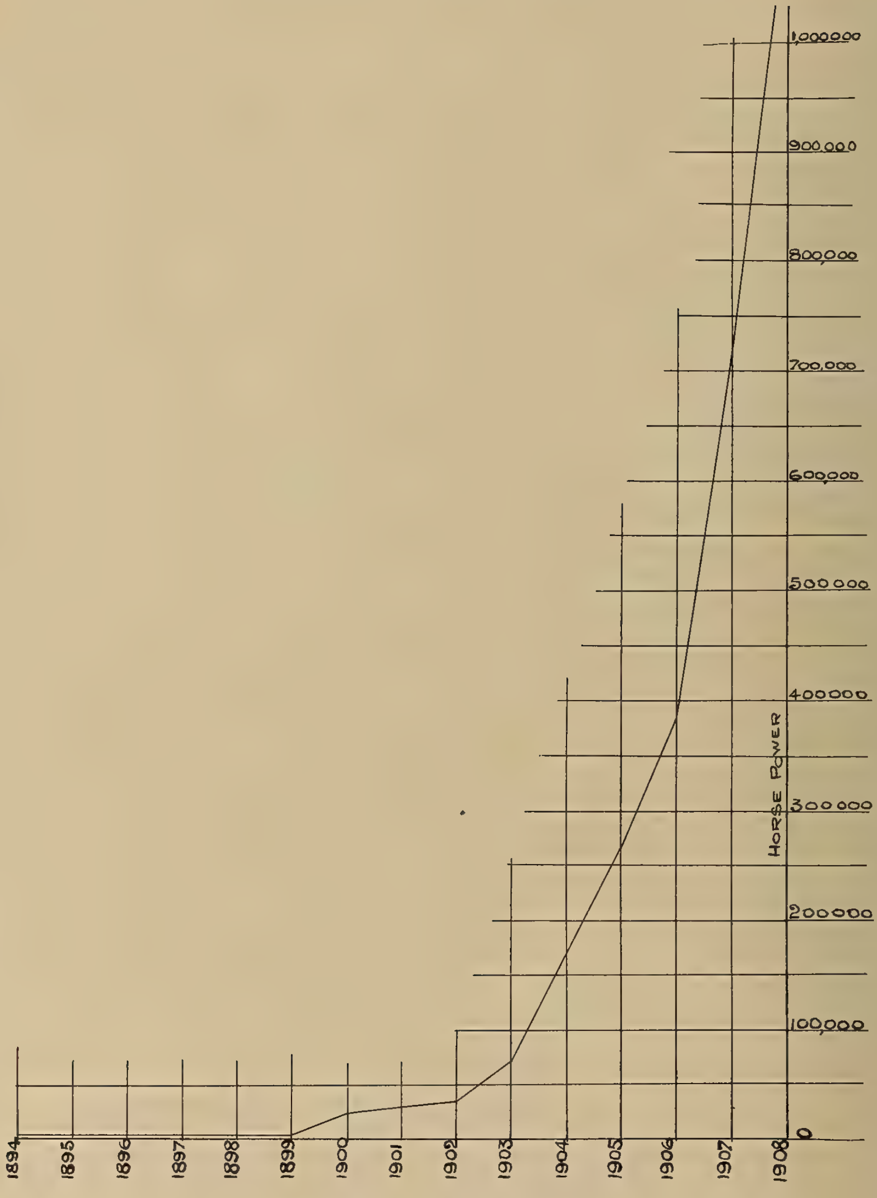
Seven and a half years ago the *King Edward* was first placed in service, and since that time the turbine engine has made very rapid strides; its growth has been quite unprecedented in the annals of steam engineering. There are now some 118 vessels fitted with Parsons turbines actually in service, and a further 61 under construction, representing a total horse-power of over 2,019,000, of which total 1,035,000 horse-power is completed, and 984,000 horse-power under construction. By reference to the diagram the growth of the marine turbine at the end of each year since its inception will be readily seen.

By far the greatest step in the adoption of steam turbines was that taken by the Cunard Company in their decision to fit this type of engine to the express liners the *Lusitania* and *Mauretania,* and one cannot pay too high a compliment to the courage and foresight which the Cunard Company displayed in venturing upon the step from the 8,000-horse-power turbines of the *Queen* to the 70,000-horse-power turbines of the *Lusitania* and *Mauretania.* When it is considered that the low-pressure turbine in the *Queen*—the largest marine turbine then constructed—was 6 feet in diameter, 20 feet in length, and 25 tons weight, as compared with the Cunarder's low-pressure turbines of approximately 17 feet 6 inches diameter, 50 feet in length, and 300 tons weight, it will at once be realized what a very great departure in size the building of the Cunarder's turbines involved, and the builders deserve every recognition for the very successful results attained.

The following table, giving the total horse-power of Parsons marine turbines completed and under construction, may be of interest:

Country.	Horse-Power.
Great Britain	1,264,000
United States	118,000
Germany	176.000
France	175,000
Japan	109,000
Austria	20,000
Belgium	22,000
Italy	22,000
Russia	60,000
South America	53,000
Total approximate h.-p.	2,019,000

The steam turbine, as evidenced by its large adoption, continues to find great favour for cross-channel steamers, high-speed ocean-going vessels and modern war vessels, not only in Great Britain, but in almost every country on the Continent, and in the United States, Japan,



TOTAL HORSE-POWER OF PARSONS MARINE STEAM TURBINES, COMPLETED TO THE END OF EACH YEAR, FROM 1894 TO SEPTEMBER, 1908

and South America. The lead given by the British Admiralty in adopting the turbine for all modern war vessels is being closely followed by all the principal navies of the world.

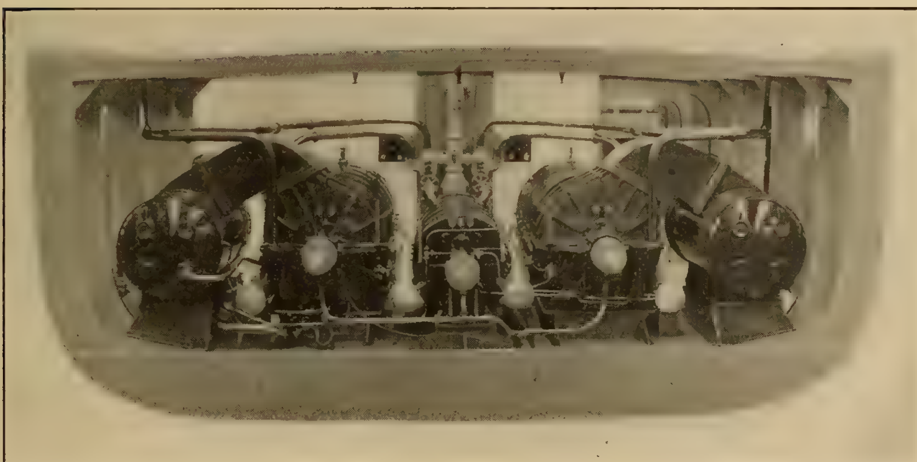
Other types of marine turbines are now being introduced. In the United States we have the Curtis, and on the Continent the Rateau, the Zoelly, the A. E. G., and the Melms-Pfenninger types.

The results of the three United States scouts *Birmingham, Salem* and *Chester,* fitted with reciprocating engines and the Curtis and Parsons turbines, respectively, have been fol-

lowed with great interest, and the further results of the exhaustive series of trials which it is understood the United States Navy propose to run with these vessels under actual service conditions will be awaited with still greater interest. On the official trials the *Salem*, fitted with Curtis turbines, obtained very good results, showing higher economy and speed than the *Birmingham*, fitted with reciprocating engines. The *Chester*, fitted with Parsons turbines, has shown superior economy to the *Salem* at all speeds. The extra speed attained with the *Chester* on the full-power trial, as compared with the *Salem*, for the same coal consumption, represents about 14 per cent. additional effective horse-power.

In the new torpedo boats under construction for the German Navy it is understood that four different types of turbines are to be tried, viz., the A. E. G., the Zoelly, the Melms-Pfenninger and the Parsons. The results of the trials of these vessels will furnish further interesting comparisons.

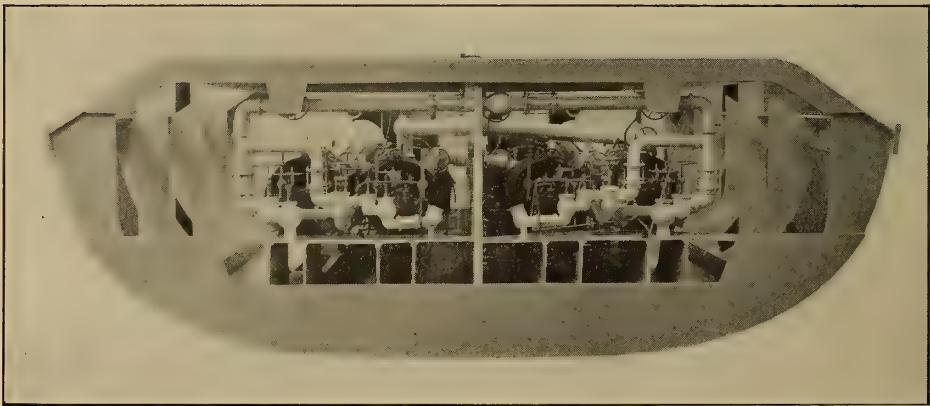
Coming to the design and disposition of marine turbines, a difference of opinion appears to exist as to whether two, three, four or even a greater number of shafts are most suitable from both an economical and a practical point of view. The builders of the Curtis, the Zoelly and similar types of turbines appear, so far, to prefer two shafts; whilst, on the other hand, with the exception of the yacht *Narcissus*, where twin screws were fitted, three and four shafts have been universally adopted with the Parsons type. In a two-shaft arrangement of turbine machinery better propeller efficiency may possibly be obtained as compared with three or four shafts; but the fact must not be lost sight of that propeller efficiency has to go hand-in-hand with turbine efficiency, and increased propeller efficiency by reducing the revolutions can only be obtained by a sacrifice in the efficiency of the turbines. In marine work it is usual to aim at the best total efficiency, which necessarily involves a compromise between turbine and propeller efficiencies, to minimize water or coal consumption in relation to speed of vessel. There is a great deal to be said in favour of the distribution of the total power over several shafts and the placing of tur-



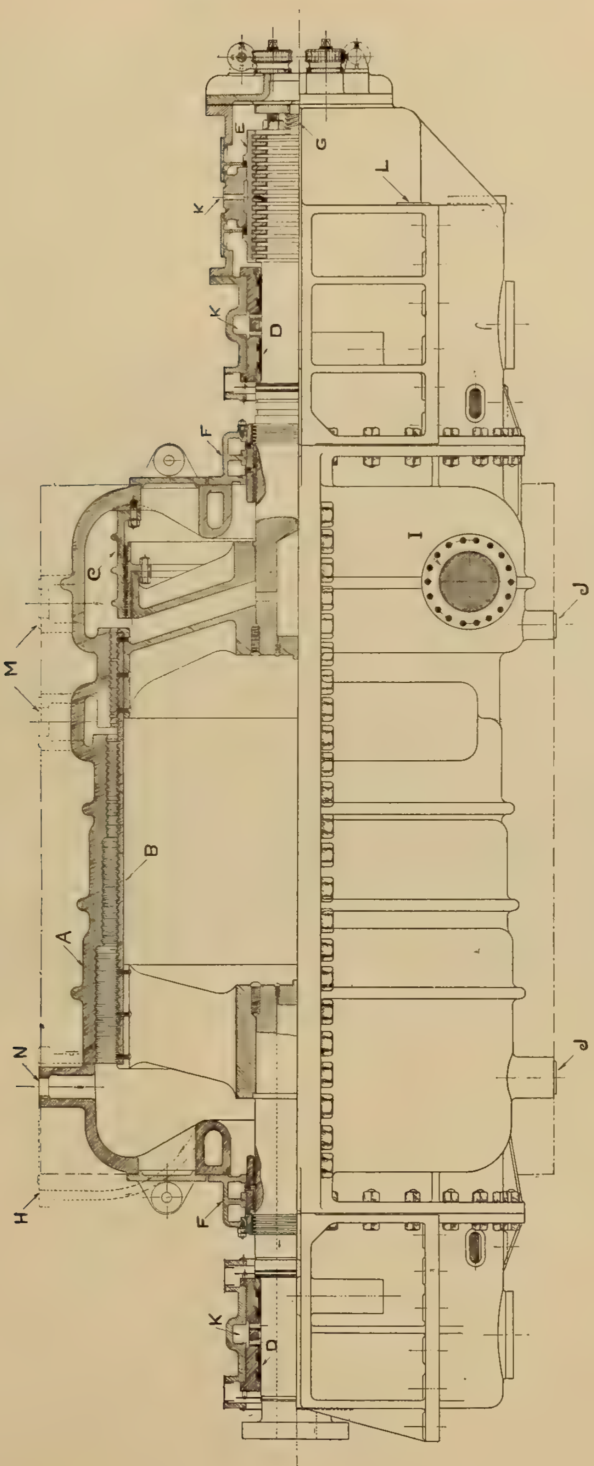
ARRANGEMENT OF PARSONS MARINE TURBINES FOR THREE SHAFTS. THE PARSONS MARINE STEAM TURBINE CO., LTD., WALLSEND-ON-TYNE

bines in series, as in the Parsons system; it not only reduces the weight of the machinery and increases the propulsive efficiency of the steam, but greatly improves the conditions for periodical examination and overhauling on board ship. By this subdivision of the power over several shafts the turbines are much smaller, the weights to be dealt with are considerably less, and the work of opening out the machinery for inspection is greatly facilitated. Although multiple turbines may entail, in some war vessels, additional floor area in the engine space, the turbines are smaller in diameter, and less head room is consequently required for overhauling, thereby enabling the protective deck to be kept lower, if desired. The increased efficiency obtainable on a given weight permits of reduced boiler installation and a saving in length of boiler spaces. In some modern war vessels the demand exists for extensive water-tight subdivision of machinery spaces. In such cases, multiple shafts would appear to be specially advantageous. Moreover, in the case of a breakdown of one shaft, the available remaining power is greater with either a three or a four-shaft arrangement as compared with only two shafts. As an instance of the utility of multiple shafts, the case of the *Mauretania* may be cited. With one of her propellers removed, owing to its being seriously damaged, she has run several voyages, using three shafts out of the four, with very little reduction in speed; and having unfortunately damaged a second propeller recently, she has still been able to run on her two remaining shafts.

The three-shaft arrangement of Parsons turbines, with one high-pressure and two low-pressures, as originally fitted in the pioneer mercantile vessel, the *King Edward,* still proves the most advantageous for merchant work, except for very large powers. For torpedo boats, the three-shaft arrangement of turbines in series, with one high-pressure, one intermediate-pressure and one low-pressure, as fitted in the original *Turbinia,* is favoured, on account of economy in weight and steam consumption. In large war vessels a four-shaft arrangement, with one high-pressure and one low-pressure on each side of the vessel, is usually adopted, although other combinations have been designed. The placing of the high-pressure turbines in series in four-shaft arrangements may come into favour in the near future, in view of the additional economy obtainable by such a combination.



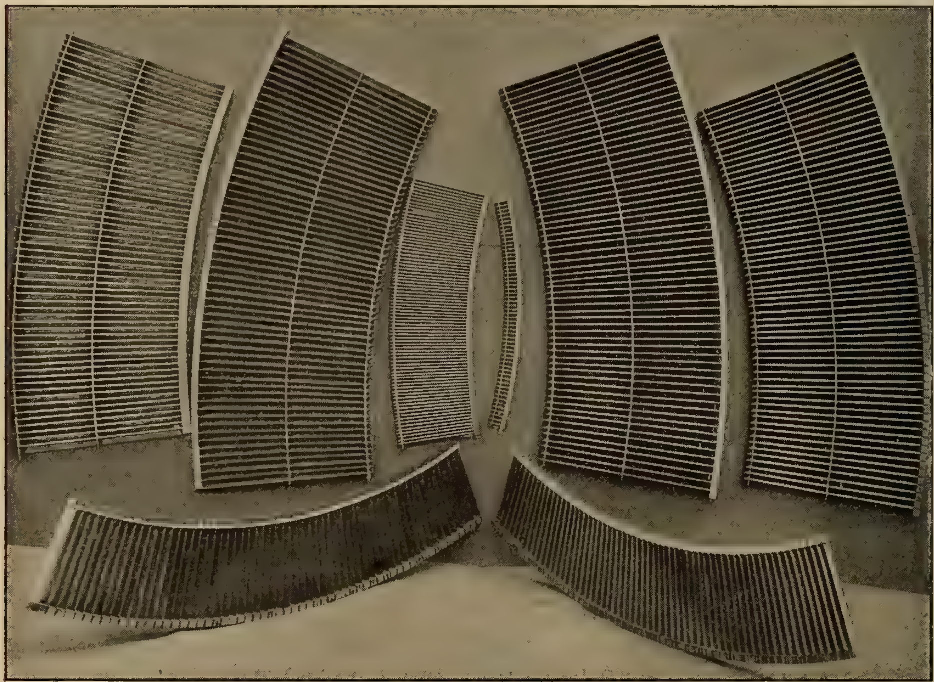
ARRANGEMENT OF PARSONS MARINE TURBINES FOR FOUR SHAFTS. THE PARSONS MARINE STEAM TURBINE CO., LTD., WALLSEND-ON-TYNE



PLAN OF PARSONS HIGH-PRESSURE MARINE TURBINE. UPPER HALF SECTIONAL ELEVATION. LOWER HALF EXTERNAL VIEW

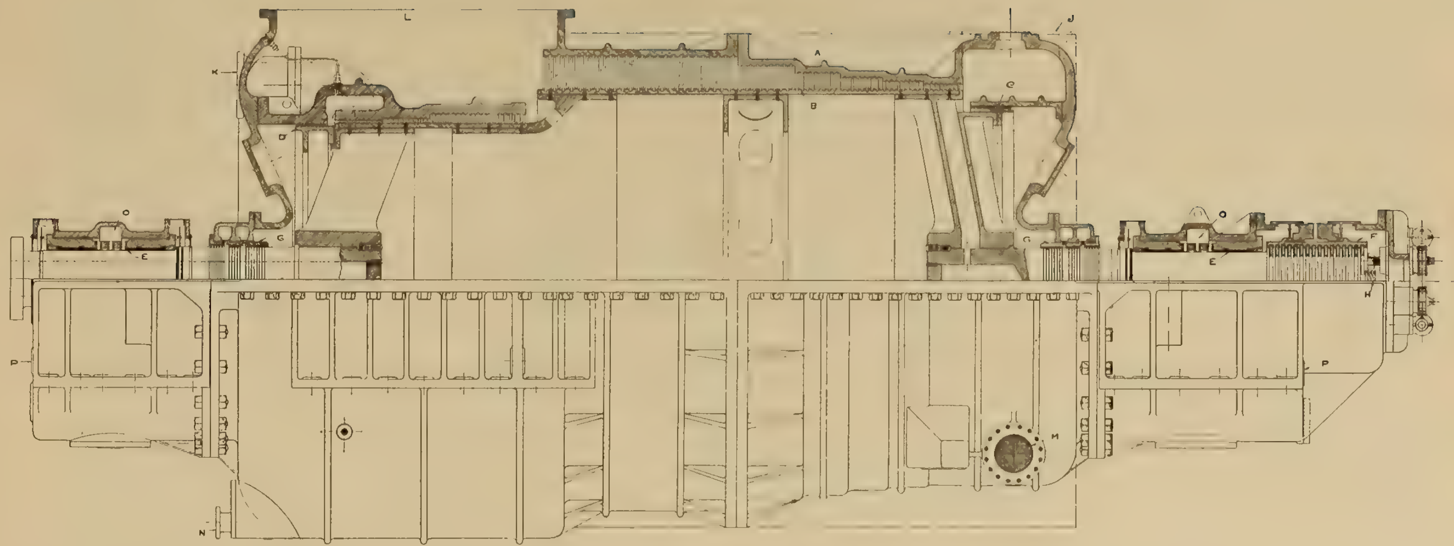
A, Cylinder. *B*, Rotor. *C*, Balance Piston. *D*, Bearing. *E*, Adjusting Block. *F*, Steam-Packed Glands. *G*, Worm for Actuating Governor. *H*, Exhaust to Low-Pressure Turbine. *I*, Steam Inlet. *J*, Turbine Drain. *K*, Oil Inlet. *L*, Oil Drain. *M*, Bye-Pass Connections. *N*, Boss for Relief Valve.

The question of maintenance of efficiency and economy under the wear and tear of long-continued service is an important one. At the moment, the Parsons turbine, owing to its wide application to warships and mercantile vessels, is the only system from which extensive experience has been gained in this respect. The result of such experience establishes the fact that, with ordinary care, the economy of the Parsons turbine is fully maintained after years of running. This maintenance of economy is due to the low steam velocities employed. Experience has proved that, with high steam velocities, erosion of the blades occurs, the rate of erosion increasing rapidly with increase of velocity. Such erosion is followed by a falling off in efficiency, which grows worse until the time arrives when it is found necessary to renew the blades or buckets. Very interesting experiments on this subject have been carried out and published recently in Germany by Dr. F. Marguerre. The dismantling and carrying out of such operations on board ship strikes one as being a matter of difficulty, and, for various mechanical reasons, there would appear to be a limit to the possible number of such renewals. The velocity of steam in the Parsons turbine is considerably below that at which it is found erosion takes place, and in consequence the blades are not liable to wear, a fact which is evidenced by actual experience; and renewals are, therefore, not necessary. The *King Edward* has now completed her eighth season, and the *Queen Alexandria* her seventh, and the blading of the turbines of these vessels has been found to be in a perfect condition; the writer is assured by the managing owner, Captain John Williamson, that, if anything, the economy is better now than when these vessels were first put in service.



VARIOUS SIZES OF SECTORS, ILLUSTRATING MANNER IN WHICH TURBINE BLADES ARE HELD TOGETHER

In regard to the manœuvring quali-

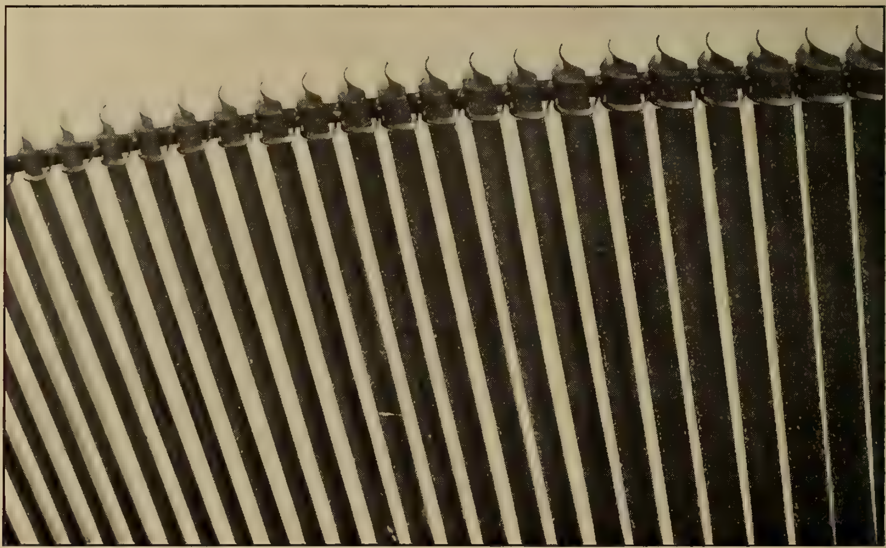


PLAN OF PARSONS LOW-PRESSURE MARINE TURBINE. UPPER HALF SECTIONAL ELEVATION. LOWER HALF EXTERNAL VIEW

A, Cylinder. *B*, Rotor. *C*, Ahead Balance Piston. *D*, Astern Balance Piston. *E*, Bearing. *F*, Adjusting Block. *G*, Steam-Packed Gland. *H*, Worm for Actuating Governor. *J*, Low-Pressure Turbine Steam Inlet from High-Pressure Turbine. *K*, Astern Turbine Steam Inlet. *L*, Exhaust to Condenser. *M*, Low-Pressure Manœuvering Steam Inlet. *N*, Turbine Drain. *O*, Oil Inlet. *P*, Oil Drain.

ties of turbine-driven vessels, with a four-shaft arrangement astern turbines can be fitted on either two or all of the shafts; but in the case of a three-shaft arrangement, it is considered more convenient for the two wing propellers to be arranged for reversing, similar to that of a twin-screw vessel. The question of reversing power is entirely one of arrangement to meet the conditions required. In the actual manœuvring of a vessel the primary consideration would appear to be the promptness in which the machinery can be reversed from one direction to another, and in the turbine engine full steam can be, and often is, turned on as fast as any simple valve can be opened, and the time occupied in reversing the engine is a matter of a few seconds. The experience gained in manœuvring the many vessels fitted with turbines, from the torpedo boat to the largest war vessels and mercantile ships, without a serious mishap of any description occurring, would seem to be conclusive as to the safety with which turbine-propelled vessels can be manœuvred.

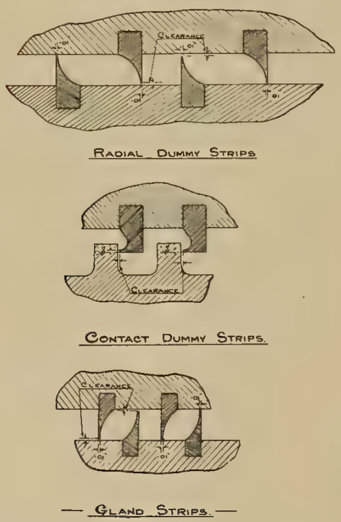
As a natural outcome of experience gained, several modifications in the details and design of the Parsons turbine have been made within recent years to increase both the mechanical and steam efficiency. The important factors upon which the proportions of turbines are based are the pressures, velocities and percentages of moisture in the steam as it gradually expands from one row of blades to another; and the chief losses of efficiency are due, first, to skin friction of the steam coursing through the small openings between the blades; secondly, to unavoidable leakages, and thirdly, to eddy-current losses arising from insufficient blade velocity. To reduce the friction losses in the steam to a minimum, the blades require to be of good shape and of smooth surface, the form conducive to the highest efficiency being obtained by actual experiments. The second loss by leakage, due to clearance, is governed by consideration of the expansion of the metals used in the construction of the turbines and the safe running limits found by experience. To reduce leakage losses, it is obvi-



ENLARGED VIEW OF PORTION OF SECTOR OF BLADING IN PARSONS TURBINES, SHOWING THINNING OF BLADES AT TIPS

THE MAURETANIA ON THE MEASURED MILE

ously advantageous to reduce the working clearance to a minimum. In the Parsons turbine the clearances are in the direction of greatest rigidity of the structure, and can be easily maintained. There is no trouble in actual practice in maintaining fixed clearances over the tips of the blades, and to reduce these clearances to a minimum the ends of the blades are milled to a thin edge, as shown in the illustration. It will be observed that the thinned tips present very small surface, and, in the event of accidental contact, the tips of the



ARRANGEMENT OF DUMMY STRIPS IN PARSONS TURBINE

blades will grind away and clear themselves. For a similar reason, the ahead and astern dummies and the gland fins are tapered away, as also shown in the illustration. With a view to maintaining, as far as possible, a uniform clearance at all temperatures in the ahead dummies of the contact type, the arms of the wheel which connects the spindle to the drum have, in turbines constructed within the last year or two, been made hollow, as shown on the sectional drawing of the turbine, to allow of admitting steam to the shaft, the shaft also being made hollow for a certain length, to equalize any differences in expansion arising from unequal temperatures between the spindle and the casing.

The type of blading and method of fitting which was adopted in the original turbines of the Parsons type are still adhered to. In some quarters, however, there is a demand for the adoption of some formation of assembled blades in sectors. Many proposals have been suggested to meet this demand, and the illustration shows a method which is now being adopted by several builders as best meeting the requirements, with practically no departure from past successful practice. The method consists of binding the ordinary caulking sections and blades together by means of a brass wire passing through holes drilled in the sections and in the blades. The blades and sections are threaded on the wire tightly into a groove in a former, the binding strip is brazed on, and the whole of the blading is gauged and finished ready for inserting into the grooves in the rotor and cylinder, respectively. Each section or packing piece is then caulked between the blades by means of special caulking tools in the same manner as the method of blading where each blade is put in individually. It is claimed that the advantage of building up blading in sectors can be carried out concurrently with the work of machining the cylinders and spindles, and that it facilitates the progress of construction when the time arrives for the fixing of the blading.

In the original design of Parsons turbines the longitudinal adjustment and clearance of the dummies were regulated by the position of a finger piece fixed on the turbine shaft just outside of the cylinder casing at the forward end, but it was thought that some arrangement should be made to enable the clearance of the dummies to be correctly checked inside the cylinder. In recent designs a micrometer gauge has been adopted for obtaining the clearance at the dummy

itself. By means of this micrometer the clearance can be measured and regulated, if necessary, almost to one-thousandth of an inch.

The steam-packed glands where the turbine shaft passes through the cylinder casing are, in recent designs of the Parsons turbine, made quite independent from the main cylinder, which permits of examination of these gland rings without interfering with the main turbine covers.

The question of the combination of low-pressure turbines with reciprocating engines for obtaining economy of steam in moderate-speed vessels was dealt with in a paper read before the Institution of Naval Architects at their spring meetings this year, and the two vessels then referred to as being under construction to be fitted with the combination system have now been launched. It is, therefore, expected that the trials of those vessels will not be long delayed. It is also expected that the yacht *Emerald*, fitted with this combination system, will run exhaustive trials before the end of the present year.

So remarkable has been the development of the steam turbine during the last few years that one ventures to hope still further improvements may be made in the very near future, and that its application may be extended to a still wider field than at present.

STEAM CONDENSING PLANT FOR CARGO STEAMERS

By D. B. Morison

THERE is no detail in connection with the propelling machinery of a cargo steamer which receives such casual attention, both in design and maintenance, as the condenser, and yet its influence on the economical production of power may be made very considerable indeed.

In designing a condenser its size is usually based on so many square feet of tube surface per horse-power, the tubes being conveniently disposed according to standard practice, but without any particular regard for obtaining high surface efficiency.

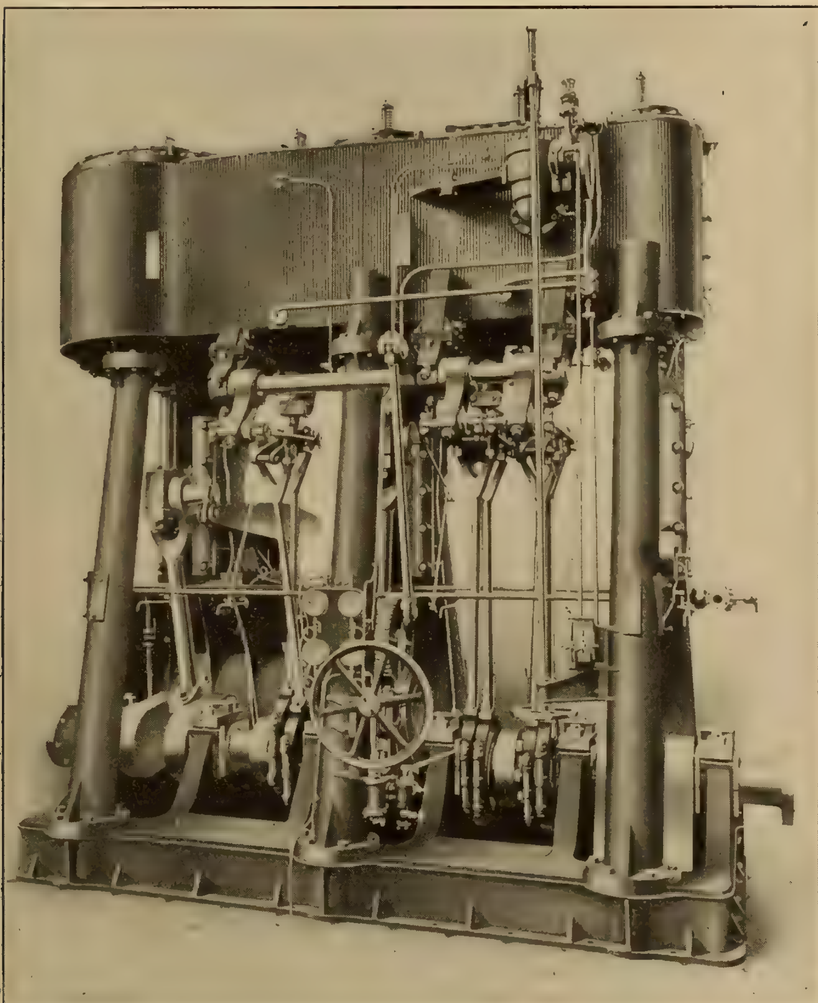
Again, the capacity of the circulating pump is usually based on such a proportion of the low-pressure cylinder as experience has shown to be necessary; but although experience is a very safe guide, yet the best results from any engineering proposition can only be obtained when experience is combined with an adequate appreciation of the laws governing that proposition.

Since the advent of the steam turbine, with its essentially high vacuum, the problem of surface condensation has been dealt with by many investigators, the effect of which is seen in electrical plants on land; but the marine condenser, and particularly the cargo-boat condenser, remains practically the same as it was decades ago. This is all the more astonishing when it is remembered that considerable economies, at present remaining latent, can be rendered effective without any additional cost, with less weight, less pumping power and no extra attention on the part of the engineer.

It is well known that the vacuum which produces maximum steam-economy in a reciprocating engine is comparatively low and is determined in a great measure by the ratio of the cylinders and the proportions of the exhaust ports and passages; but as cargo-boat engines are standardized within small limits, it follows that the most desirable vacuum for this particular type of engine can be closely approximated. It is this definite degree of vacuum which, in the interests of efficiency, should be maintained in the condenser under any condition of sea-water temperature to be met all the world over, the condenser and pumps being arranged and proportioned accordingly. Of course, it is impossible to keep a marine condenser quite clean; but, on the other hand, it is recklessly wasteful to allow the tubes to become furred up on the water side and choked with oily filth on the steam side, as is unfortunately only too often the case. Therefore, in determining the tube surface a fair margin should be provided for the loss of efficiency due to a reasonable amount of inevitable dirt, great care being exercised that the disposition of the surface is such as will render it capable of condensing the maximum amount of steam under any given conditions. It is folly to suppose that a large tube surface per indicated horse-power is a guarantee for good vacuum, as the mere addition of tubes is an absolute waste of money unless those tubes are so arranged that they can effectively condense steam. Ineffective surface also reacts on pumping power, since an altogether unnecessary amount of

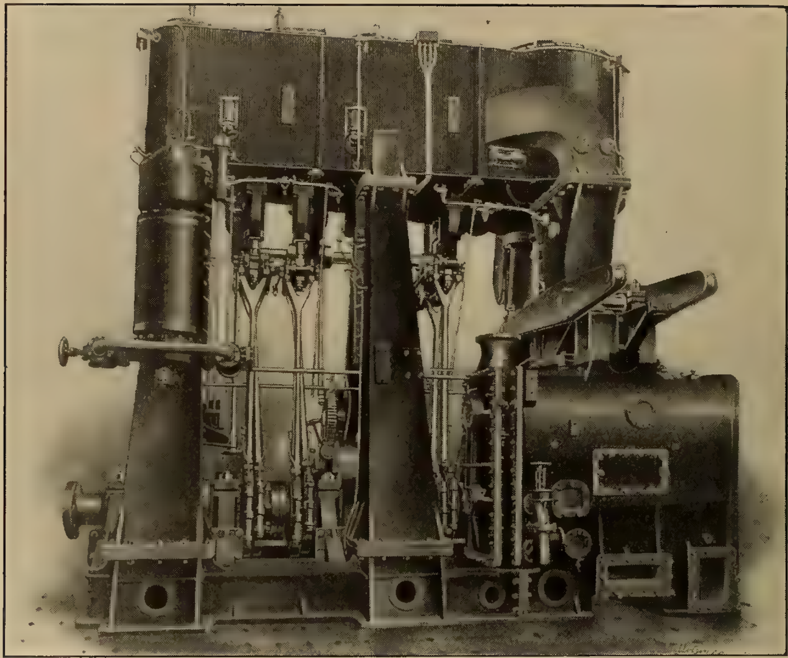
circulating water is required, and a continuous loss in power-efficiency is the natural consequence.

Quite a radical departure from ordinary marine condenser practice

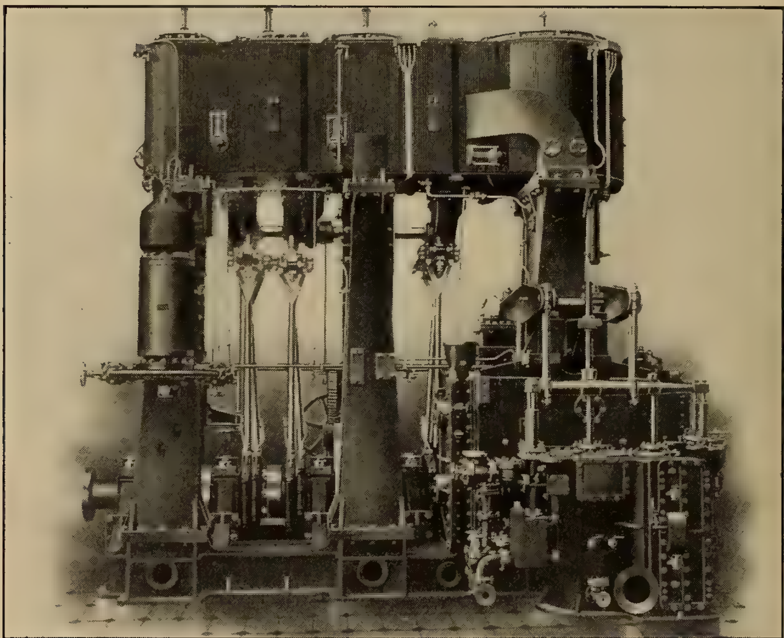


TRIPLE-EXPANSION ENGINES FOR S. S. GWLADYS, BUILT BY RICHARDSONS, WESTGARTH & CO., LTD., HARTLEPOOL

has just been made in the S.S. *Gwladys,* owned by Messrs. W. T. Symonds, P. Samuel & Co., of Cardiff, and engined by Messrs, Richardsons, Westgarth & Co., Ltd., Hartlepool. The condenser is constructed on the "Contraflo" system and, as will be seen from the illustrations, it is much shorter than usual, and permits of a conveniently open engine at the back, together with advantageously short tubes. With the object of obtaining high surface-efficiency the tubes are arranged in compartments, and the steam is so guided as to flow evenly over the entire length of each tube. The flow is uniform from the exhaust inlet towards and finally into the air-pump



ENGINES OF S. S. GWLADYS. BACK VIEW SHOWING CONTROL VALVE TO COOLER, PUMPS REMOVED



ENGINES OF S. S. GWLADYS. BACK VIEW, SHOWING CONTRAFLO CONDENSER WITH PUMPS COMPLETE

suction, the change in direction of flow being in tubeless spaces, so that the steam is compelled to pass over all the tubes in one compartment and be uniformly distributed in the tubeless passage before entering the next nest of tubes.

mean velocity. The design in basis is, in effect, an elongated wedge arranged for practical convenience in superimposed sections, the steam flow being across the tubes and at right angles to the falling water.

In what is known as the counter-

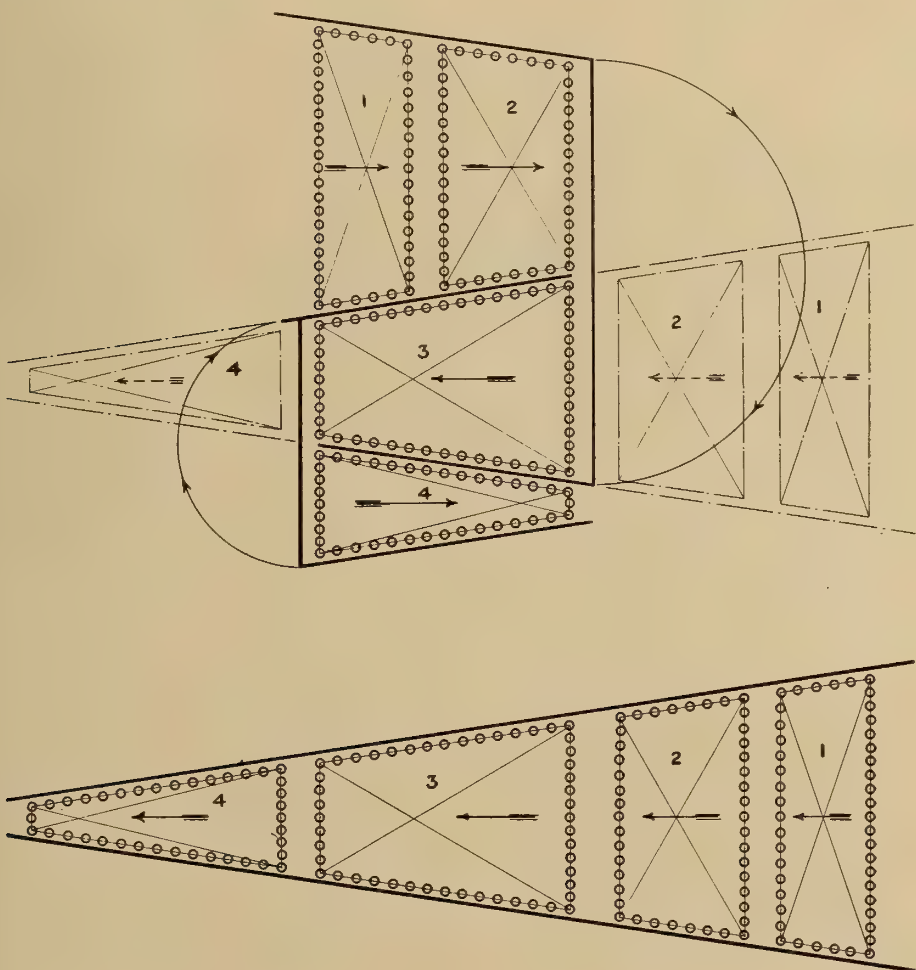
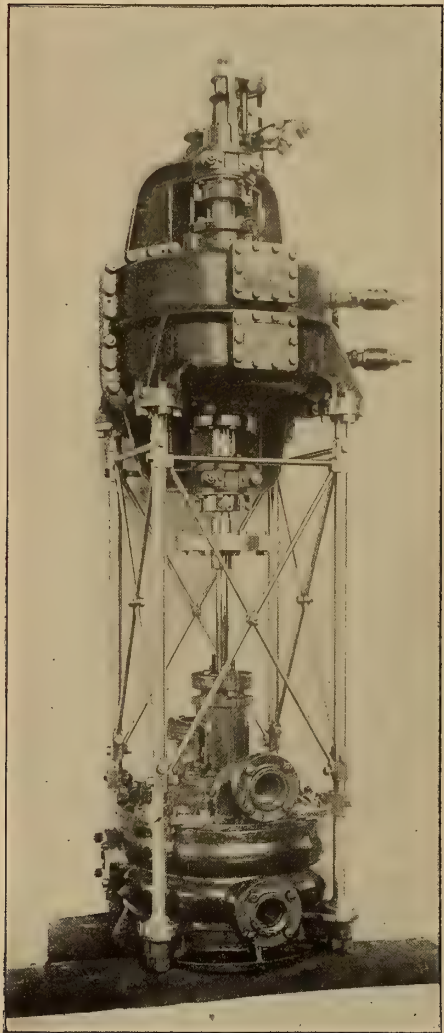


DIAGRAM OF CONTRAFLO CONDENSER

Efficiency of tube surface on the steam side is very favourably affected by velocity of flow, so by giving the steam a zigzag downward course there is, compared with an ordinary condenser, an increase in the distance through which the steam travels and a corresponding increase in its current condenser the steam flow is along the axis of the tubes and the reversal of flow takes place within the tube nest, so that there is a distinct tendency for the steam to short-circuit some of the surface, whereas in the "Contraflo" design all the available steam passes over all the

tubes of one nest and is uniformly distributed in the tubeless passage before entering the next nest, and with the usual zigzag arrangement of tubes it is brought more intimately into contact with the condensing surface when flowing across the tubes than it is when flowing along or parallel with their axes—hence high efficiency of condensing surface is obtainable with this system.

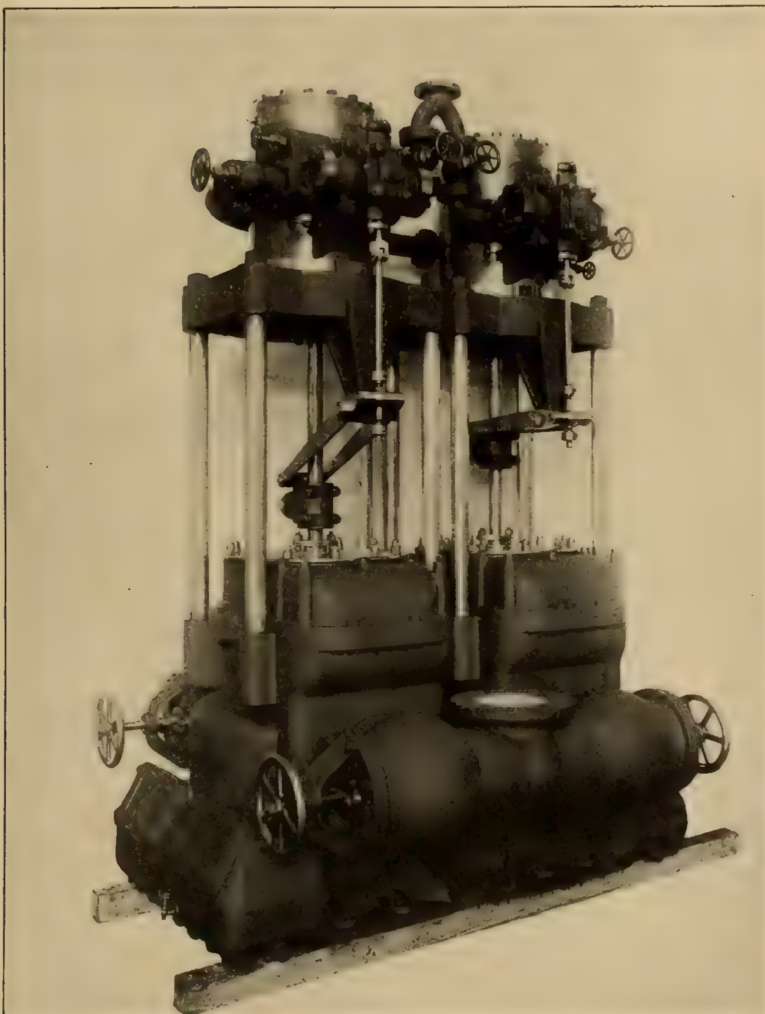


VERTICAL TWO-STAGE TURBINE HOT-WELL PUMP WITH STEAM TURBINE DRIVE. THE INTERNATIONAL STEAM PUMP CO., NEW YORK

If the steam entering a condenser were simply water-vapour containing no air the usual air pump would be unnecessary; but in practice air is always associated with steam, and its non-conducting properties are so great and its presence in a condenser affects the heat transferring capacity of the tube surface so prejudicially that no surface condenser can be efficient unless the air pump is sufficient to prevent the ratio of air to steam in the condenser bottom rising so high as practically to put out of action all the tubes which it surrounds. At the exhaust inlet the percentage of air to steam is naturally very small, so that the temperature of the mixture practically corresponds to the temperature of water-vapour at the particular vacuum prevailing; but as the steam is condensed, so the air ratio increases, until it reaches a maximum at the air-pump suction. This gradual increase in air richness is, however, accompanied by a gradual decrease in temperature, and when this temperature corresponds to that of the inlet circulating water no further condensation is possible. The condenser is, in effect, automatically reduced in size, and as a consequence the temperature in the remaining portion rises and the vacuum falls. The size of an air pump for any particular installation at a given vacuum is therefore regulated, not by the power of the engine, but upon the weight of air normally passing into and through the system. In a cargo boat the air entering a condenser is usually most excessive, and is contributed by the low-pressure gland, by the air discharged into the boiler by the ordinary single-acting ram feed-pumps, by the various auxiliary engines exhausting into the condenser, and by insidious leakage through defective joints. As a consequence, the air pump is often quite unable to deal effectively with the air, with the result that a considerable portion of the tube surface is air-drowned either partially or en-

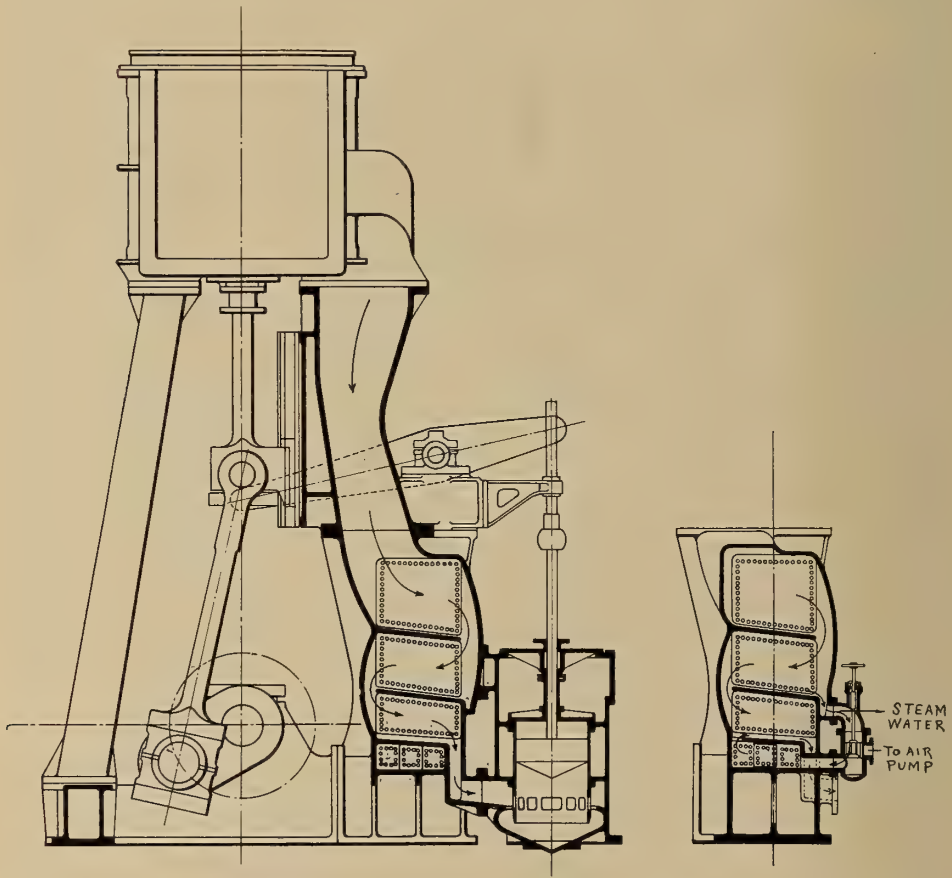
tirely. In hot climates this action is intensified, and the fall of a few inches of vacuum is now by custom regarded as inevitable and accepted quite as a matter of course; yet a cargo boat is essentially a proposition demanding ever-increasing vigilance to secure all those economies which contribute to commercial success.

The efficiency of an air pump working on the wet system is largely determined by the temperature of the water passing through it, as whenever a vacuum is produced in the pump barrel which corresponds to the boiling point of the contained water, vapour is given off and the production of a higher vacuum in the barrel becomes impossible. But air will only flow into an air pump when the vacuum therein is higher than it is in the condenser, so it follows that the temperature of the water passing through an air pump must



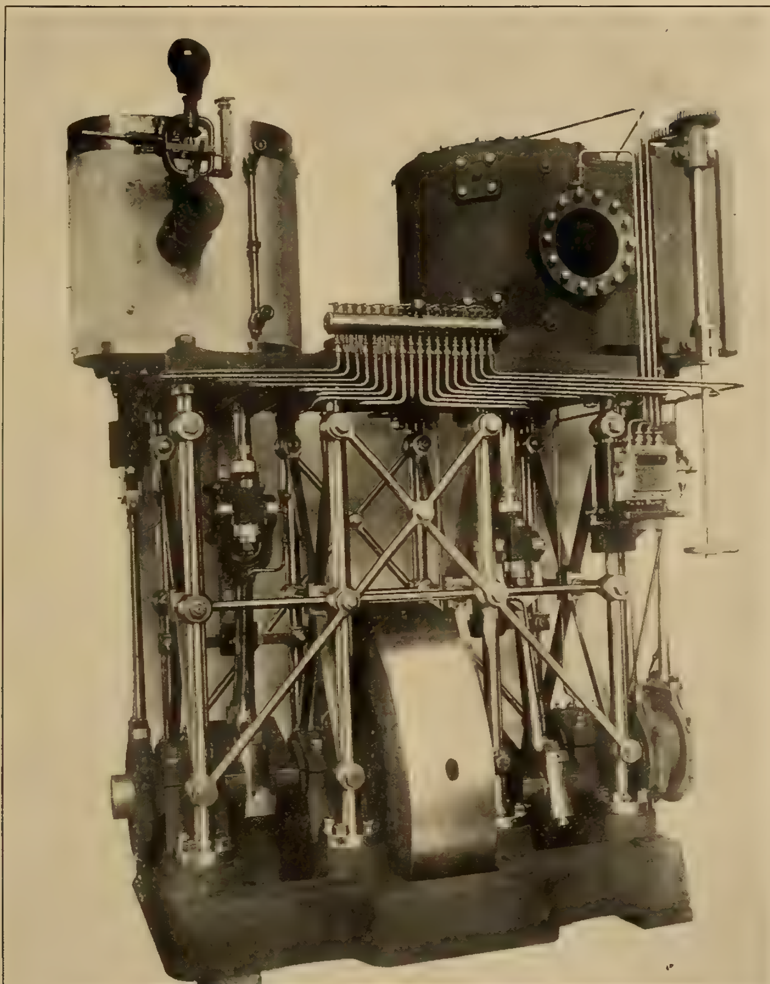
THE BLAKE SIMPLEX CROSS-CONNECTED, DOUBLE-ACTING FEATHERWEIGHT AIR PUMP. THE INTERNATIONAL STEAM PUMP CO., NEW YORK

be less than the temperature corresponding to the vacuum in the condenser in order that air can be withdrawn therefrom. On the other hand, as soon as steam is turned into water in a condenser it is at the temperature corresponding to the vacuum, and if the temperature of this water is reduced a thermal loss results. Therefore, a wet air pump and a condenser are antagonistic with respect to temperatures, and in order to obtain the most economical thermal results the difference between these temperatures should not exceed that which the air pump demands in order that it may effectively rarefy the condenser. Obviously the water and the air should be withdrawn by separate pumps; but in a cargo boat, where simplicity of mechanism is a first essential, a single air pump on the wet system has been found to be the best compromise. In an ordinary condenser, when a drop of water is formed on a top tube it splashes over tube after tube, thereby becoming gradually cooler until it reaches the bottom of the condenser at the minimum temperature the conditions will permit. If this temperature is unnecessarily low, or, in other words, if the air pump can deal effectively with the air when water at a higher temperature passes through it, then there is a definite thermal loss. Variation in the temperature of this water produces flexibility in the air-with-



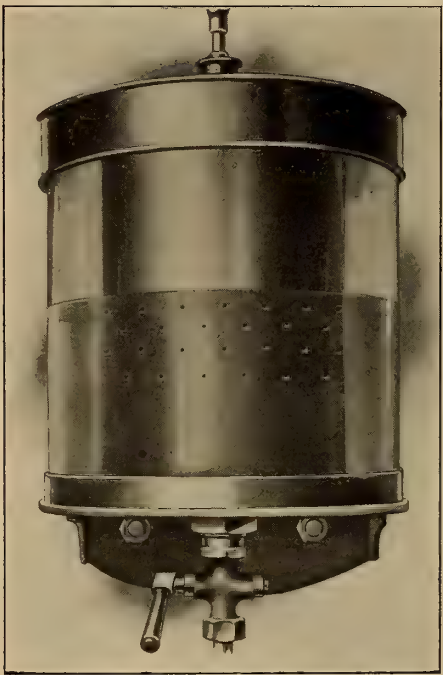
ARRANGEMENT OF MARINE ENGINE WITH CONTRAFLO CONDENSER

drawing efficiency of the air pump, so that, if the temperature can be adjusted to the requirements of the pump, the hottest possible feed-water can be obtained with any given vacuum and any given air leakage. control valve. As the condensed water in the upper compartments flows over the minimum of tubes it is cooled to a minimum extent, and under normal air-leakage and normal sea-water temperature the air pump



SINGLE VERTICAL MARINE ROTATIVE DRY-VACUUM PUMP FOR SCOUT CRUISER SALEM. INTERNATIONAL STEAM PUMP CO., NEW YORK

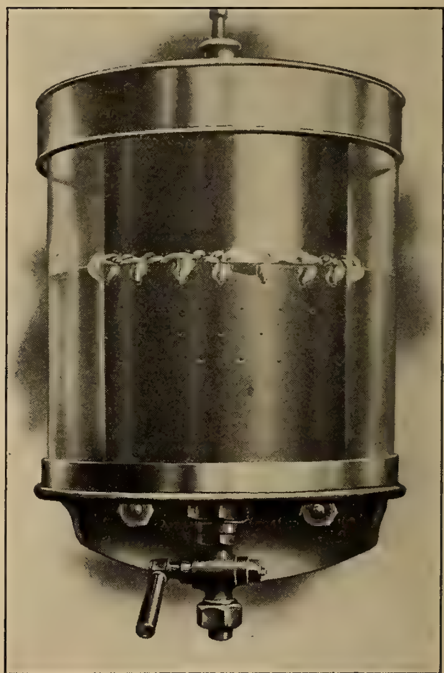
A condenser designed to effect this object is divided into compartments in series, and arranged below the condenser, and divided from it is a water-cooler through which the greater part of the condensed water can be passed at will by way of a should be of such a volumetric capacity as will permit of this hot water passing through it without prejudicing its ability to rarefy the condenser efficiently. Under abnormal air-leakage, however, when in tropical waters or when it is desired to develop maxi-



WEIGHTON'S AIR GAUGE, FIXED-BELL TYPE

mum power from the main engines regardless of a slight sacrifice in thermal efficiency, the condensed water is passed through the cooler until a temperature is reached which will permit of the maximum vacuum being obtained. Therefore, the effects produced by this system which will appeal to marine engineers are: ability to obtain the highest temperatue feed-water under any given conditions and ability to maintain the most economical degree of vacuum in all climates, whilst the power-efficiency of the engines may also be raised to a maximum when desired by raising the degree of vacuum considerably above the normal.

In carrying out experiments on condensers investigators have hitherto experienced very great difficulty in determining the quantity of air discharged by an air pump, and as a consequence exact data have been most difficult to obtain. Moreover, engineers on shipboard, and also those in charge of electrical stations on land, have perforce been compelled to accept blindly the losses which abnormal air-leakages produce without in any way being able to determine their extent. In view of the extreme importance of air-leakage on the efficiency of any condensing plant, the invention of Professor Weighton, whereby the air discharge can be visually ascertained, must be regarded as exceedingly valuable, and one calculated to have a far-reaching effect on the economical working of condensing plants generally. The apparatus is very simple, there being two forms, one with a fixed bell and one with a floating bell. The former consists of a glass cylinder, closed at the bottom, containing a stationary bell, the interior of which is in communication with the air discharge pipe from the air pump. Arranged around the surface of the bell are several rows of small holes, one below the other. The containing cylinder is filled with water until the uppermost row of

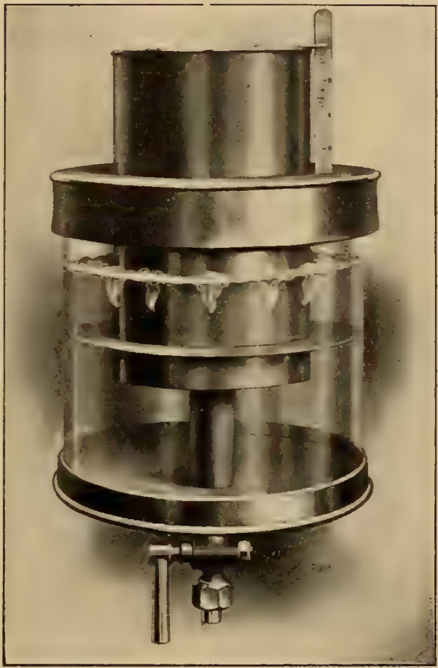


WEIGHTON'S AIR GAUGE RECEIVING AIR

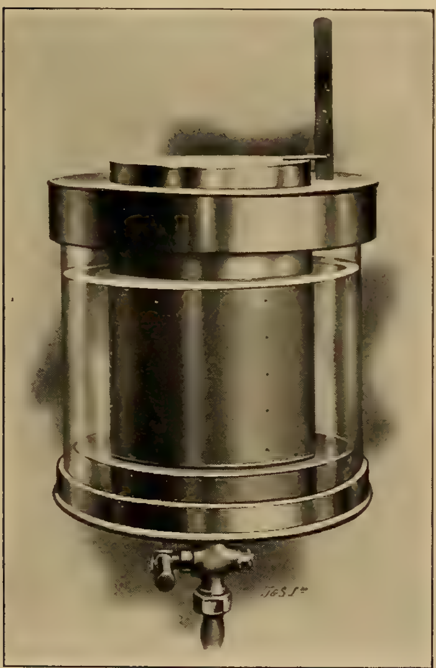
holes is just submerged. On air being admitted under the slight pressure to the interior of the bell, the water-level within the bell is depressed below the first row of holes and air escapes therefrom.

On more air being admitted, additional rows of holes are successively brought into operation, and from original calibration the number of cubic feet of air being discharged under any given condition is visually ascertained.

The floating bell type will, however, probably prove the more useful, as a cylinder of glass is unnecessary, and, moreover, the air pressure under all rates of discharge within the capacity of the apparatus is practically constant. The bell, in this case, is fitted with a buoyancy chamber, and the container is filled with water until the bottom of the bell is just not touching the bottom of the cylinder; the top row of holes will then be slightly below the water-level. On air being admitted the



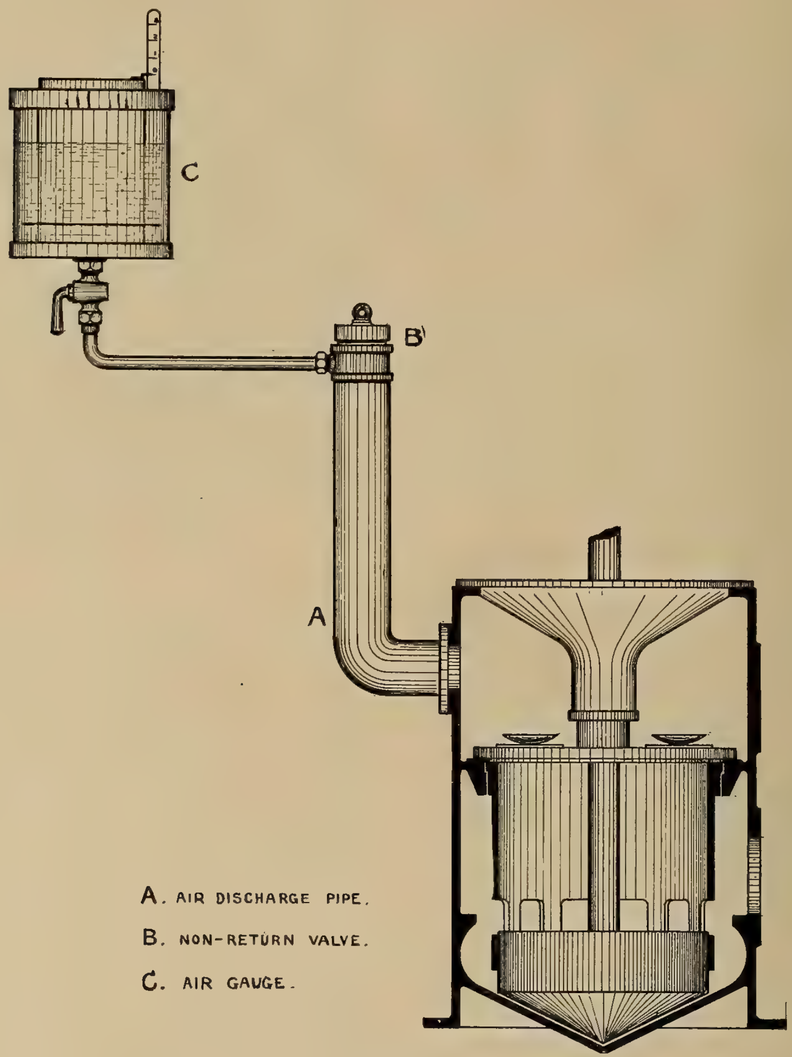
WEIGHTON'S AIR GAUGE, FLOATING-BELL TYPE, RECEIVING AIR



WEIGHTON'S AIR GAUGE, FLOATING-BELL TYPE

bell rises until successive rows of holes are brought above the water-line until the apparatus is discharging its maximum capacity. The air discharge-pipe from the air pump is fitted with a non-return valve, and when it is desired to ascertain the quantity of air passing through the system the valve is lowered and the air gauge rendered operative. By the use of this instrument engineers can determine the minimum air-leakage which it is practically possible to obtain from any plant, and thus not only reduce the power absorbed by the air pump to a minimum, but establish whether such a minimum is within its capacity. Both of these points are of great importance in the economy of the plant, as unnecessary power absorbed by the air pump is a direct loss which goes on day in and day out, whilst if the air-leakage is allowed to become greater than the air pump can deal with, except at a sacrifice in vacuum, there is a wasteful expenditure of circulating

water pumping power and a thermal loss in the feed-water. With steam turbines the degree of vacuum, as is well known, has a very great effect on steam consumption, and the loss



GENERAL ARRANGEMENT OF WEIGHTON'S AIR GAUGE

of an inch or so of possible vacuum on a vessel of high power—as, for example, a warship—means an unnecessary waste of coal, a decreased radius of action, or reduced speed.

Having decided how great is the detrimental effect of air in a condensing plant, the problem is how to minimize the quantity admitted to the system. Assuming that all joints subject to vacuum are carefully made air tight, the great source of air-leakage in the main engine is the low-pressure piston-rod gland, the amount of leakage depending on the kind of packing used and the care with which the gland is packed and maintained. Most metallic packings, otherwise perfectly satisfactory, are

very unsuitable for keeping air out, as also are many fibrous packings. After a long series of trials with the quadruple engines at Armstrong College, Newcastle, a packing in which copper is deposited on compressed paper was found to be the best for all glands subject to vacuum.

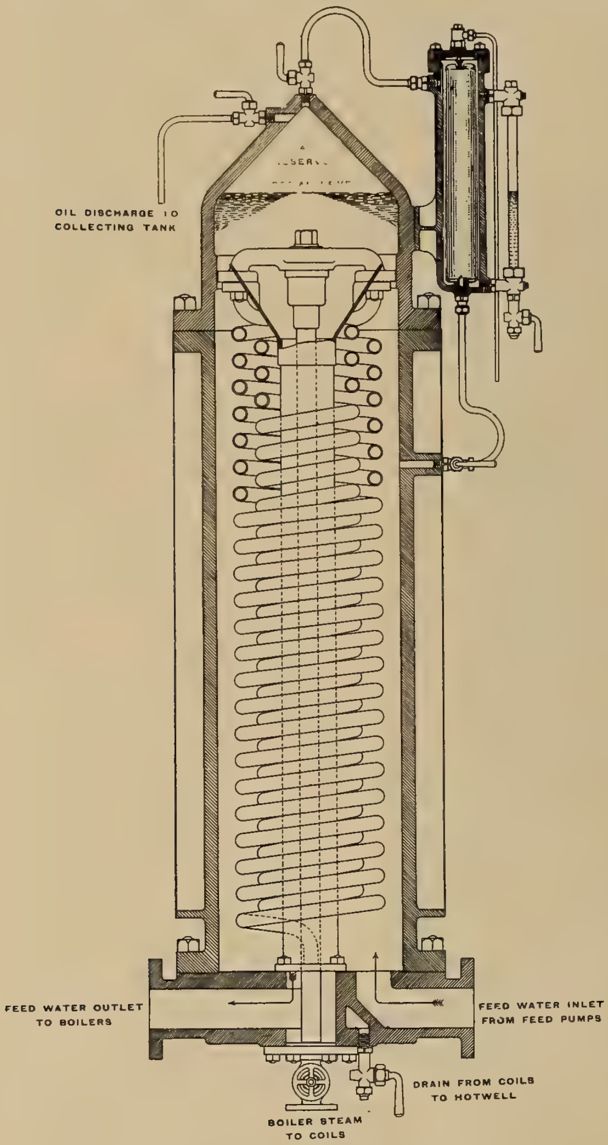
SURFACE FEED-WATER HEATER AND AIR EXTRACTOR

In passenger and other high-power vessels the ordinary ram feed-pump is practically obsolete, and has rightly given place to the float-controlled, independently-driven pump, which delivers the feed-water to the boiler free from air in suspension; but in ordinary cargo boats the ram-feed pump, worked by the main engines, is still universally employed, and, when no precautions are taken, is undoubtedly responsible for a large amount of air in suspension being sent into the boilers with the feed-water. Steamship owners naturally hesitate to add to the moving machinery in an engine department having a very small staff, and therefore it is becoming standard practice in ordinary cargo boats to fit a feed-water heater which automatically discharges all air in suspension and much of the air in solution in the feed-water before it enters the boiler. Such an apparatus is shown in the illustrations. By its use the feed-water is raised to a high temperature, and at the same time the objectionable air is got rid of. When this heater is fitted to engines having independently - driven, float - controlled pumps, the air discharge-valve operates only at long intervals, whereas in a cargo boat with ram pumps the discharge from the air valves is very frequent; but in both cases the air entering the boiler is quite a negligible quantity.

In vessels equipped with turbine engines engineers have found by bitter experience that it is commercially suicidal to exhaust the various auxiliary engines into a main condenser unless the engines are maintained at an exhaust pressure above atmospheric; but in cargo boats, especially in those of the very cheap class, it is still the practice to exhaust the steering engine, ash hoist, etc., into the main condenser, although by so doing the loss of power in the main engines, by the falling vacuum, is often greater than the aggregate power of all the auxilaries combined. Competition in the future will, however, compel ship-owners and their advisers to avoid what is obviously bad engineering practice, when by an initial outlay which is a mere trifle on the cost of the boat a definite saving may be continuously effected.

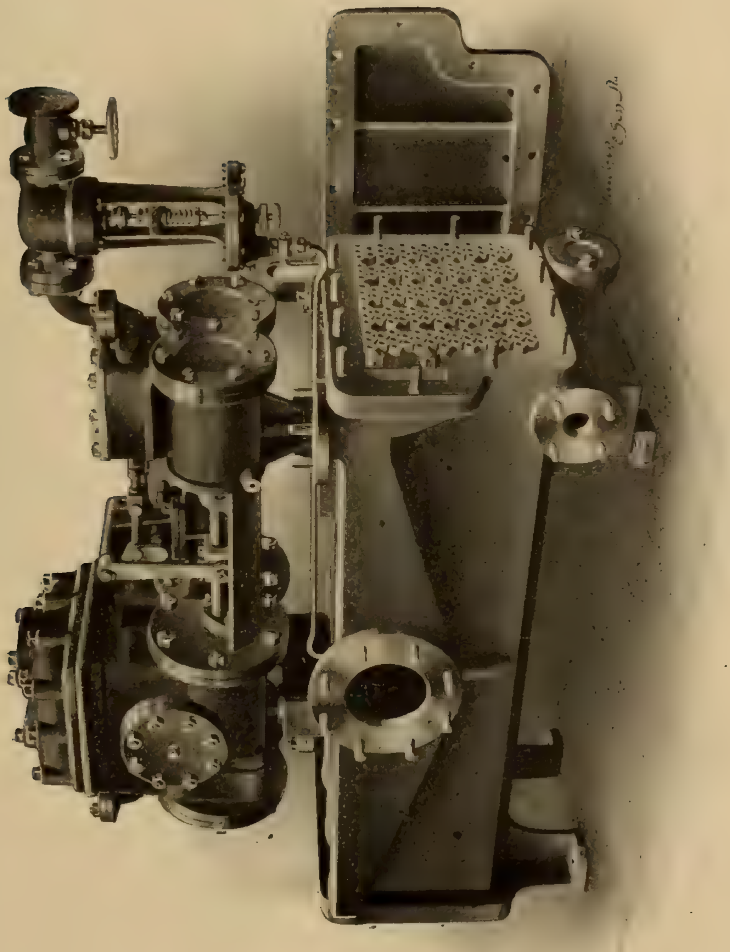
In the case of a steering engine the exhaust is sometimes led into the valve chest of the intermediate cylinder of the main engines, and so the

difficulty of air-leakage is got over; but many engineer superintendents will not take the risk of possible accidents with this arrangement, and, moreover, the inflow of condensed water with the exhaust steam is not conducive to the efficiency of the main engines.



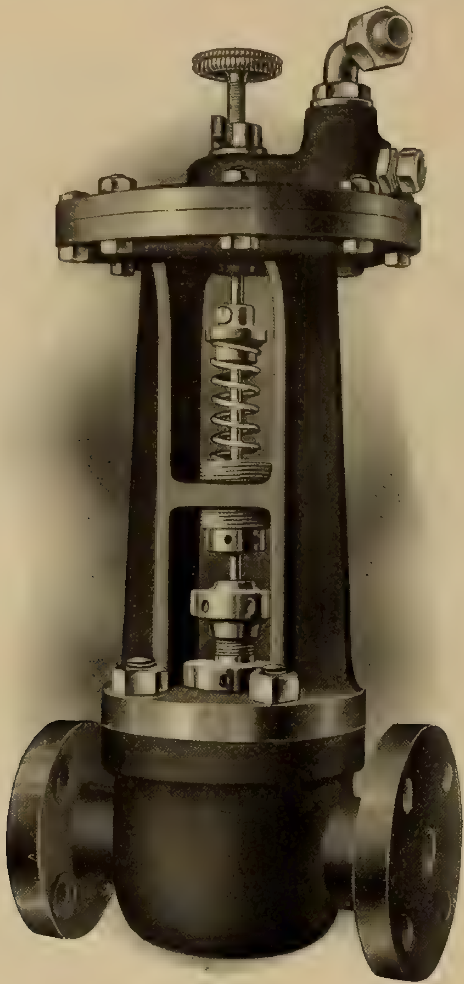
SECTIONAL VIEW OF SURFACE FEED HEATER

The demand for rapid discharge of cargo is gradually forcing a correct solution of the problem, however, as the modern donkey boiler is either very much larger than formerly or is done away with altogether and use made of a main boiler for cargo-discharging purposes. Feeding such a boiler from the sea is both dangerous and highly uneconomical, and therefore an auxiliary or harbour-condenser becomes commercially im-



WINCH CONDENSER WITH CIRCULATING PUMP AND CONTROL VALVE FOR REGULATING THE AMOUNT OF CIRCULATING WATER IN PROPORTION TO THE AMOUNT OF STEAM CONDENSED

perative. When at sea this condenser is available for all engine-room and deck auxiliaries, and if placed above the level of the air-pump hotwell the condensed water flows by gravity amongst the feed-water with great thermal advantage. As condensation takes place under atmospheric pressure, the temperature of the condensed water should, for maximum thermal effect, approach 212 degrees as nearly as possible. The condenser shown in the illustrations has been designed with this object, as the steam space is divided up into multiple compartments, each of which comes successively into use with every increase in the quantity of steam to be condensed, so on condensation taking place the resultant water is cooled to a minimum extent and flows to the hotwell at a temperature approximating 200 degrees.

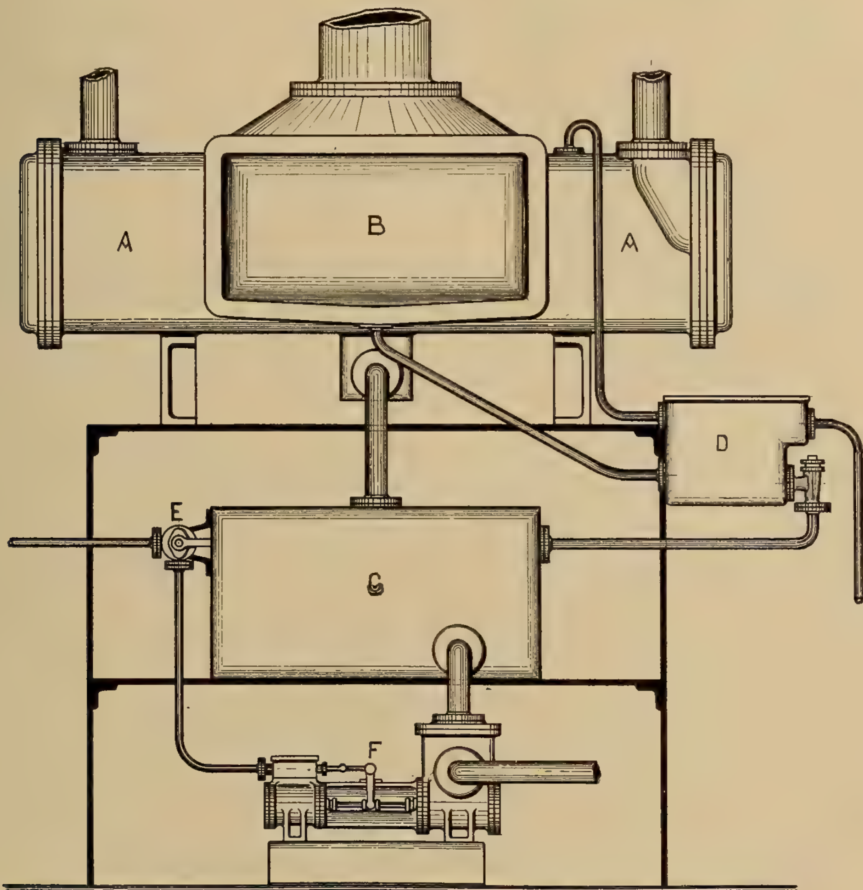


PUMP CONTROL VALVE

When at sea the circulating water may be obtained from a branch on the main circulating pipe, but in

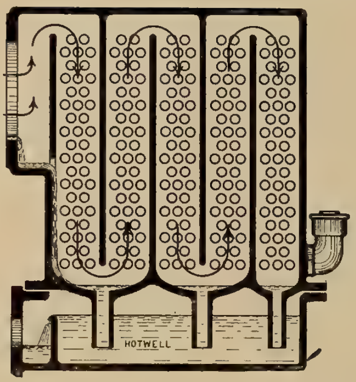
harbour a steam-driven pump becomes necessary. As the winches on deck are worked intermittently, there is naturally a great variation in the quantity of steam discharged into the condenser, and if the steam-driven pump is set for dealing with a maximum quantity, a wasteful expenditure of pumping power results, as well as an unnecessary cooling of the feed-water.

In one arrangement the amount of circulating water is automatically regulated by the quantity of exhaust steam entering the condenser, the control valve being so set that the speed of the pump is dependent on the number of winches or other auxilaries at work. This simple device is the invention of a marine superintendent, and successfully deals with what has hitherto been a troublesome problem. In many passenger vessels auxiliary condensers are worked under a slight vacuum, but as an air pump becomes necessary such a complication is unlikely to extend to cargo boats. Condensation under atmospheric conditions has also the additional advantage of enabling the



AUXILIARY CONDENSING PLANT

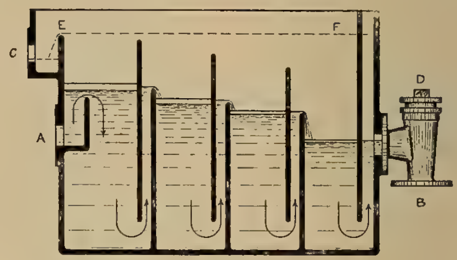
A, Contraflo Auxiliary Condenser. *B,* Oil Separator. *C,* Feed Tank. *D,* Floating Oil-Collecting Tank. *E,* Steam-Control Valve to Feed Donkey. *F,* Feed Donkey.



SECTION THROUGH CONDENSER AND HOT WELL WITHOUT OIL SEPARATOR. UPPER INLET IS FOR EXHAUST STEAM. BELOW IS THE STEAM WATER OUTLET

oil, which is so often associated with exhaust steam from auxiliary engines, to be practically eliminated in a very simple manner. In such an apparatus there is combined with the condenser an oil extractor through which the steam flows and is cleansed before entering the condenser. The oily drainage water is led to a small divided tank in which all the float oil is trapped. If the remaining water is highly emulsified, as from the use of inferior oil, it can be discharged to the bilges; but if reasonably clear, it is passed to the feed tank. In either case the engineer can ascertain what degree of care is being exercised in the internal lubrication of the deck machinery and so check any extravagant use of oil.

The successful management of a modern cargo boat is becoming more and more difficult by reason of increasingly keen competition, and as the economics of the engine department are a controlling factor in the proposition from a commercial standpoint, engineers are now keenly alive to the necessity of taking advantage of those possible savings which have hitherto remained, to a great extent, latent. Electrical engineers have given



FLOAT OIL-COLLECTING TANK

A, Oily drainage water from separator. B, Feed-water to feed tank or bilges. To discharge oil, shut cock *D*, when water will rise to *E-F*, and the floating oil flows over the weir *E* to discharge pipe *C*.

the lead in this respect, the reason no doubt being that they have as a fixed basis the cost to produce a definite unit of electrical power, whereas marine engineers have no such standard, and therefore cannot so easily focus the many minor economies which in the aggregate are the means of materially improving the credit balance on a shipping investment.

INTERNAL COMBUSTION ENGINES FOR MARINE PURPOSES

By Sir John I. Thornycroft, LL. D., F. R. S.

WHILE internal-combustion engines have been used for some time for driving launches, it is only during the last three or four years that they have come into general favour for the smaller classes of marine work. No doubt they will be improved, but they have already reached such a state of perfection that for many classes of work they are much better than steam engines. For launches of moderate powers, tenders and naval pinnaces, they are rapidly replacing steam.

Where very high speeds or extremely shallow draught are required, results are being obtained which formerly were quite impossible, the weight of the propelling machinery being so very greatly reduced. The reduction in the space occupied by the machinery, as well as the great gain in cleanliness, are also very important considerations.

For ferry-boats or harbour launches, which often spend a considerable portion of their time waiting between their journeys, internal-combustion engines show great economy in running expenses, as the waste in fuel for keeping up steam is entirely obviated, the motor being stopped as soon as the run is finished, and started up again only when the next journey is required.

In the same way that ordinary marine engines may be divided up into different classes the internal-combustion engine may be classified into three distinct types. Those most generally employed at present are of a light high-speed type, using for the most part petrol (petroleum spirit) as fuel. Some makers are, however, developing the same type of motor using kerosene, which is a much more satisfactory fuel from the point of safety than the spirit.

Another class is composed of heavier and slower-speed engines using different classes of kerosene as fuel. These are used for barges, as auxiliary power for fishing boats and for similar work. While suitable for special cases, this class cannot be said to have yet become a serious rival to steam, as the difficulties of starting and getting satisfactory reversing arrangements for the larger sizes are considerable. The greater skill which is required to understand their working than is necessary with the ordinary steam engines also makes it difficult, in many cases, to provide suitable drivers.

The Diesel engine, which must be classed among the heavier types, is so distinct that it stands alone. The advantages which are obtained with the "Diesel cycle" are so great that there is every probability of a great development of this type of motor for marine purposes in the near future. The absence of any ignition device, or vapourizing arrangement for the fuel, makes it so simple that a minimum of skill is required on the part of the attendant. Of course, the high pressure employed, and the necessity for storing air under very high pressure for starting, require special precautions; but the simplicity in working and the high fuel economy much more than counterbalances any disadvantages which these precautions may entail.

How far the Diesel engine will be able to compete with the other types for moderate powers it is impossible at present to say, as they have been

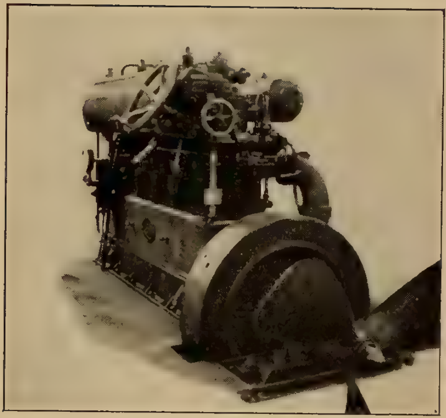


FIG. 1.—REVERSING DIESEL ENGINE; 100 HORSE-POWER

so little used for marine purposes. The compression pumps and other fittings make them an expensive engine in smaller sizes, though for larger powers there is every probability they will in the near future take a leading place.

With the exception of a few special electric-transmission Diesel installations which are working in cargo steamers on Russian rivers, the largest power internal-combustion engines for marine purposes are fitted to submarine boats. Those now in use in French submersibles are also of very high power.

The development of large power engines will, to a great extent, be on the lines of these engines, as the limitation of cylinder dimensions which, in practice, occurs with engines working on the Otto cycle does not exist, there being no fear of premature ignitions caused by hot pistons.

Engines of moderate power using kerosene have been made in large numbers, and have proved quite successful as auxiliary power for fishing boats and similar purposes. They have generally worked on the well-known "Hornsby" principle, which is very suitable, as no electric or lamp ignition is required. The drawback, however, with engines of this type is that they are necessarily heavy for their power, and their field of appli-

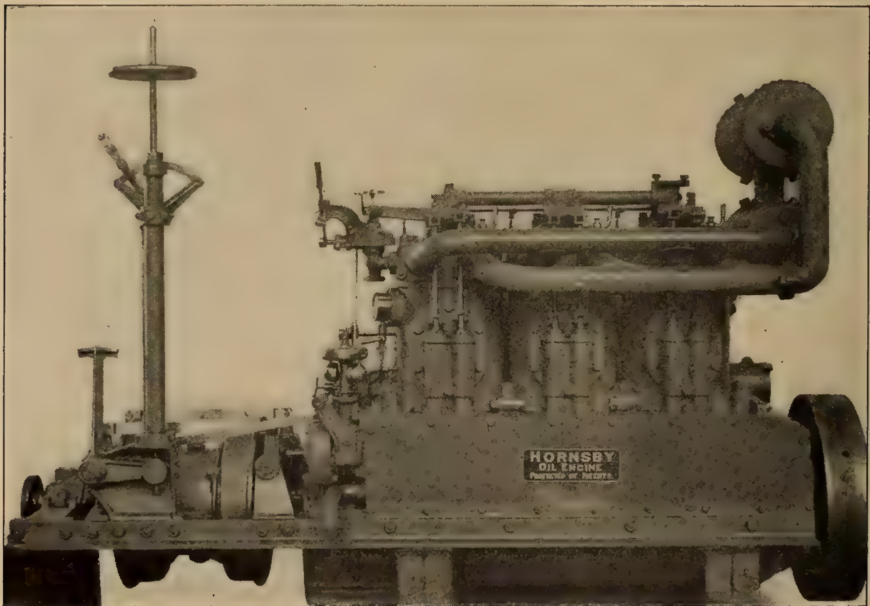


FIG. 2.—HORNSBY 3-CYLINDER ENGINE, 40-HORSE-POWER, FITTED WITH REVERSING GEAR

This engine was fitted to a 60-foot, twin-screw launch built for service in Demerara. It has been running for two years, and is managed by a colored man.

cation is somewhat limited. Makers have consequently been driven to electric ignition and internal vapourizers to produce engines that compare with high-class steam machinery in weight.

Engines of this type, for naval pinnaces and similar purposes, developing as much as 2½ to 3 horse-power per hundredweight of the complete equipment, have recently been supplied to the British and a number of foreign governments. This weight is very much greater than that of motors of the vehicle (or high-speed) type using petroleum spirit, of which a great many sets have been fitted to pleasure boats and yachts.

A considerable increase in weight is necessarily involved where kerosene is used, but even after making allowance for this there is still a very great difference between the weights of engines of the vehicle type using petrol spirit and the most efficient petroleum engines adapted for continuous and heavy running.

This is to be accounted for by the fact that the vehicle type engines are run at a very high number of revolutions, and have not, as a rule, the necessary proportions for continuous running at full power. In many of the racing launches the engines are run at speeds of more than 1,500 revolutions and give powers of upwards of 5.3 to 6.4 horse-power per hundredweight of the total equipment on a continuous run of two to three hours' duration. These are wonderful performances from a mechanical point of view; but the experience with high-speed steam machinery which is available goes to show that, for continuous service, it is not possible to produce a satisfactory machine giving more than about 3 horse-power per hundredweight. These figures are taken for engines of something under 100 horse-power, and include the necessary reversing gear, which must exist where the engine itself is not capable of reversing. It has not been found satisfactory to make engines of much less than 100 horse-power reversible.

In the larger-sized engines, which cannot be started by hand, the compressed air used for starting is also available for reversing the engine. While such an arrangement may be quite satisfactory with petroleum spirit as a fuel, it is a little uncertain when internal vapourizers are used, owing to the cooling of the cylinders which takes place with compressed air.

The weight of the engines when fitted with compressed air starting and reversing, with the necessary tanks, will not be less than the figure of 3 horse-power per hundredweight mentioned bove, and if one takes as an example an engine of about 150 horse-power, the horse-power will not be more than 1½ to 2 per hundredweight.

Engines built on the Diesel principle are specially suited for reversing with compressed air, but the lightest that have been made so far do not give more than 1 horse-power per hundredweight. This weight includes starting reservoir, silencers and all fittings up to the shaft coupling.

Fig. 3 shows a 45-foot pinnace, built for service in Demerara.

Figs. 4 and 5 represent vessels which were constructed some time ago for the Government of Nigeria for river navigation, and have proved eminently satisfactory. The two boats are identical as regards hull and machinery, except that one has a stern wheel and the other is driven by screw placed in a tunnel. The draught of each boat is 12 inches when loaded with 4 tons of cargo. The speed of the stern-wheel boat is 8 miles and of the screw boat 9 miles. The only fuel obtainable is common kerosene, on which the engines run extremely satisfactorily. The boats have run many thousands of miles in charge of native drivers, and are away from their base without any European engineer on board for as much as six weeks at a time.

The boats are used for the trans-

port of troops and stores, and also collect and carry produce of the traders to the coast.

Owing to their shallow draught they have been able to penetrate to places where no steam vessel has been able to run. It is found that natives can be trusted to handle these boats better than if they were steam-driven, as it is difficult to make them take proper care of the boilers, thus running constant risks of explosion.

Fig. 6 shows a steel motor pinnace built for experimental service at the Portuguese Torpedo School, Lisbon. It is constructed of galvanized mild steel, having three transverse water-tight bulkheads, fore cabin for accommodation of twelve seamen and aft cabin with cockpit for twelve officers. There is a steel casing over motor space and fore cabin. She is fitted with four-cylinder motor arranged for petrol or paraffin, developing 45 brake-horse-power at about 450 revolutions, and propelling the boat at a speed of 9 knots.

Fig. 7 represents a shallow-draught vessel fitted with suction gas plant. The chief feature of this machinery is the great economy in running, and though only a small number of boats are as yet fitted with it, there is no doubt that it will come into more general use. The engine is of the four-cycle, four-cylinder type, and runs at 300 revolutions per minute. It is turned by a small oil engine for starting purposes, and this engine also drives the blower for the producer.

After the main engine has commenced running the blower is, of course, not required, as the plant is then automatic.

Figs. 8 and 9 show one of four sets of submarine engines recently delivered by the writer's firm to a foreign government. There are eight cylinders with a stroke of 8 inches and a diameter of 12 inches. The engines will run in either direction, and are started by means of compressed air. The fuel used is kerosene, and the average power obtained was 300 brake-horse-power at 600 revolutions on a consumption of 0.7 of a pint per brake-horse-power per hour.

FIG. 3.—PINNACE EQUIPPED WITH DIESEL ENGINE

Fig. 10 shows an 80 brake-horse-power, four-cylinder reversing oil engine. This is an experiment by Messrs. Richard Hornsby & Sons, Ltd., and is fitted into a 40-foot boat.

FIG. 4.—STERN-WHEEL MOTOR CANOE SANDFLY

FIG. 5.—MOTOR CANOE SPIDER

FIG. 6.—MOTOR PINNACE (38 FEET LENGTH), BUILT BY J. SAMUEL WHITE & CO., LTD.

FIG. 7.—LAUNCH PROPELLED BY THORNYCROFT SUCTION-GAS ENGINE

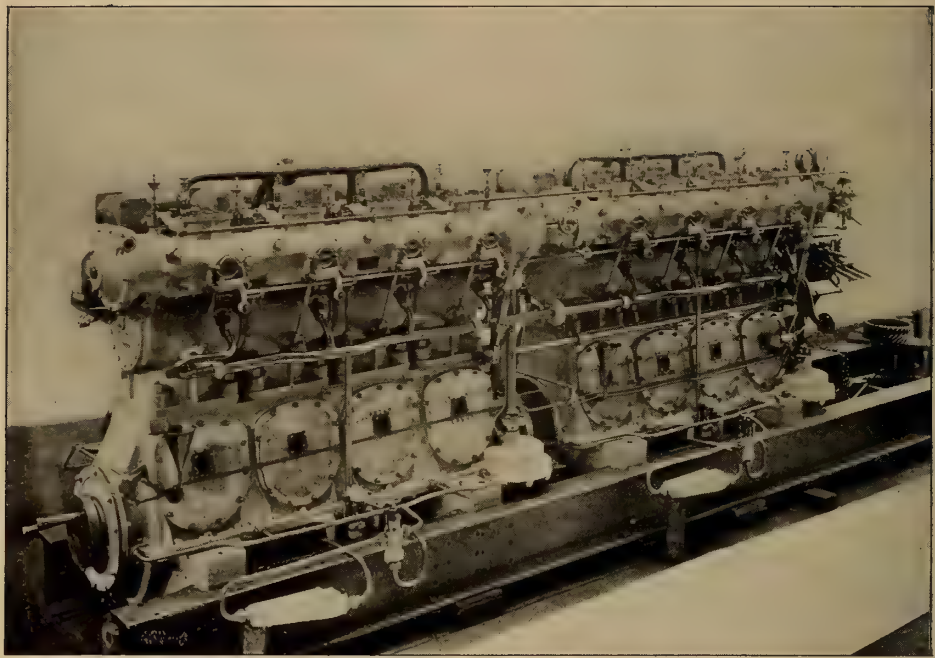


FIG. 8.—KEROSENE ENGINES FOR SUBMARINES; 300 HORSE-POWER. JOHN I. THORNYCROFT & CO., LTD., LONDON

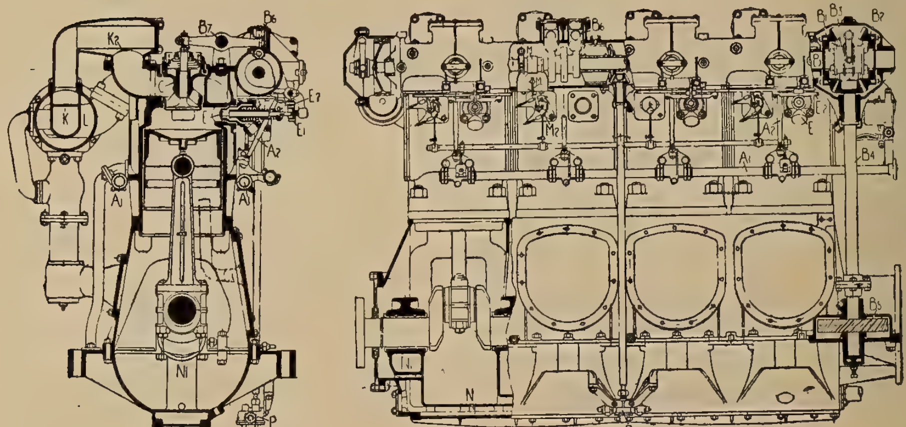


FIG. 9.—SECTION OF THORNYCROFT SUBMARINE-BOAT ENGINES

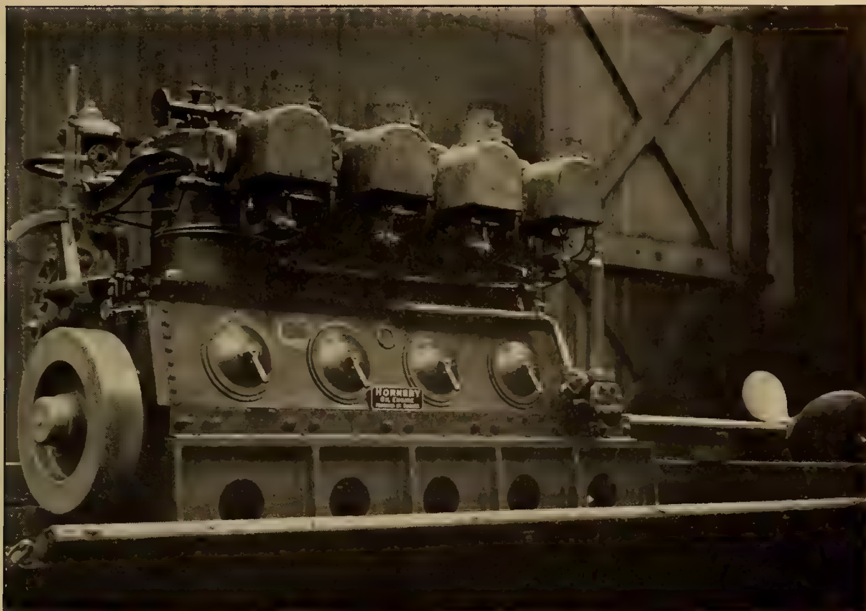


FIG. 10.—HORNSBY FOUR-CYLINDER REVERSING OIL ENGINE

The results have been entirely satisfactory; but the reversing can be done more simply for an engine of this size with a clutch, as it occupies less space and requires no auxiliary engine.

Fig. 11 represents a shipyard and engine works motor boat fitted with 34 brake-horse-power Gardner paraffin motor. This boat is strongly built, having a double skin, the inner being diagonal and the outer longitudinal, and is used for transporting men and carrying material to and from vessels in the river, harbour and open waters of the Solent. She is also used for towing barges and assisting in removing torpedo boats.

FIG. 11.—WORKS HARBOUR BOAT FITTED WITH 34-HORSE-POWER GARDNER MOTOR. BUILT BY J. SAMUEL WHITE & CO., LTD., EAST COWES, ISLE OF WIGHT

FIG. 12.—THE FIREFLY. A TYPE OF MOTOR BOAT TO BE CARRIED ON A BATTLESHIP AS A VEDETTE

The motor is fitted at the after end of the boat with large well forward, with seats for the accommodation of the men and floor space for carrying any requisite material. The steering arrangement is such that the boat can be steered and worked by one man. Suitable canopies and washstrakes for use in heavy weather are also fitted. This boat has answered the purpose for which she was built in a very satisfactory manner, and has proved to be just the type of boat for this class of work.

Fig. 12 illustrates another type of boat designed specially for the Russian Navy to be carried on a battleship or used as a harbour launch. It was fitted with two motors of 100 brake-horse-power each.

It is particularly suited to naval requirements and to stand rough seas. The wheel is situated in a watertight and bullet-proof conning tower, and the engine-room hatches can be closely battened down so that the boat can be worked in the heaviest weather.

Other boats of similar design, but with single screw, have since been built.

Fig. 13 is the same type of boat

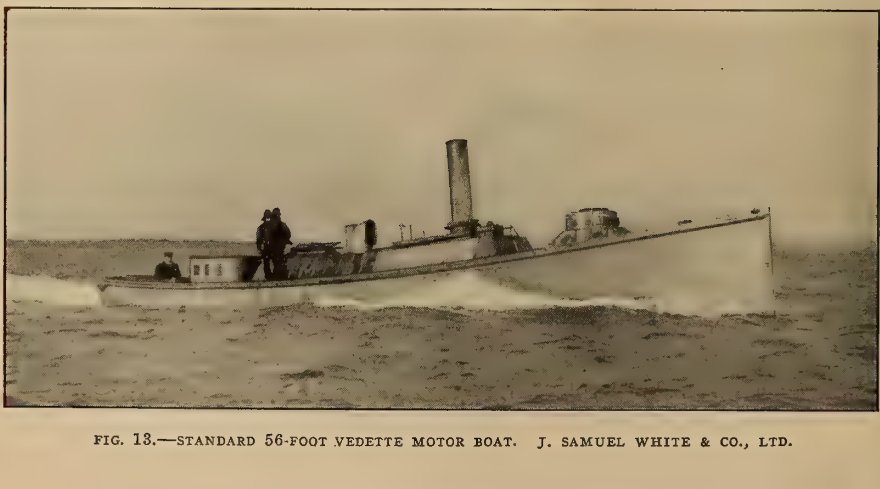


FIG. 13.—STANDARD 56-FOOT VEDETTE MOTOR BOAT. J. SAMUEL WHITE & CO., LTD.

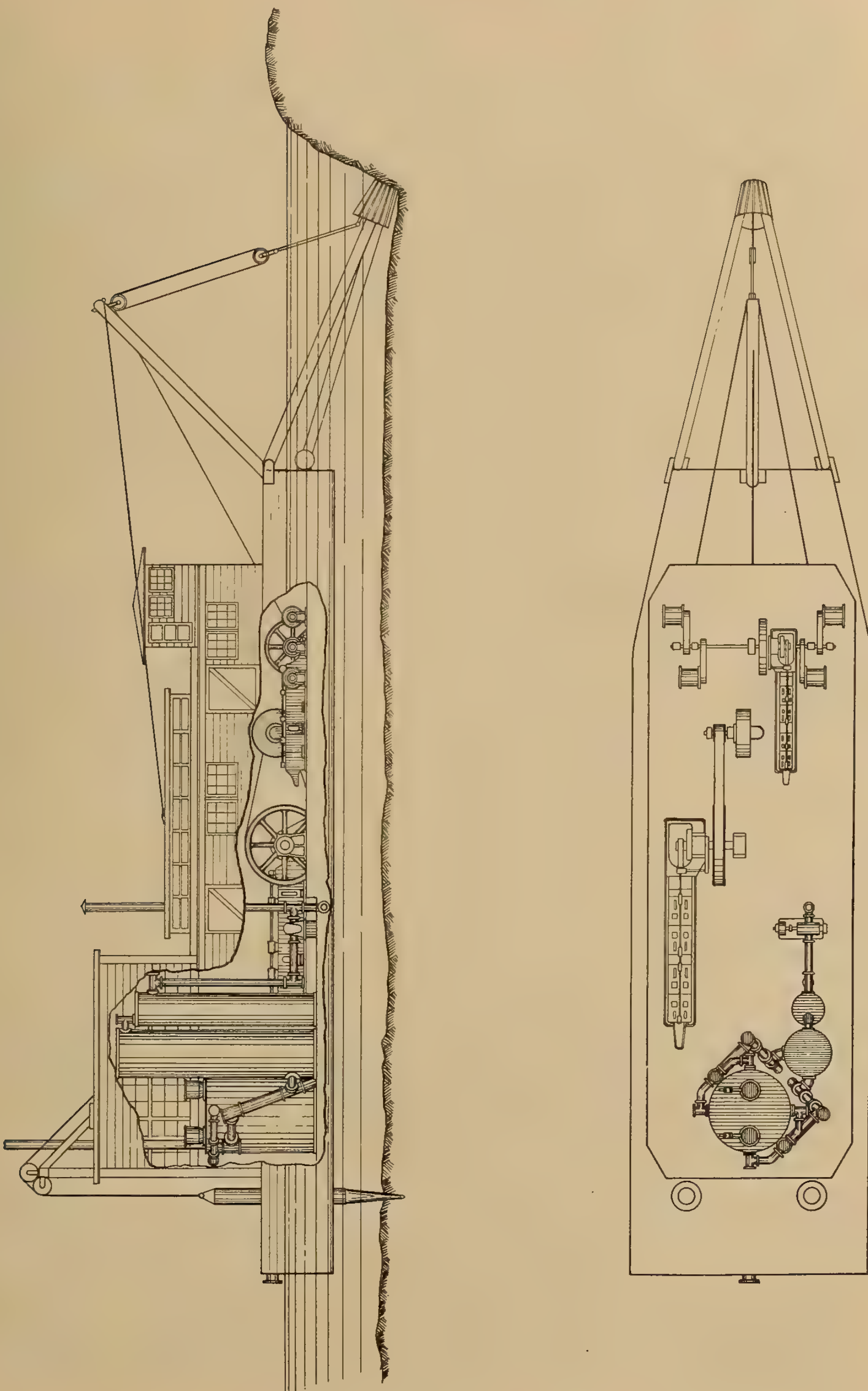


FIG. 14.—SUCTION DREDGE ARRANGED TO BE DRIVEN BY GAS POWER, DESIGNED BY GODFREY M. S. TAIT. 400-HORSE-POWER SUCTION-GAS PRODUCER PLANT, WITH RIVERSIDE HORIZONTAL GAS ENGINE

FIG. 15.—ADMIRALTY PINNACE CONVERTED FROM STEAM TO MOTOR POWER

built by Messrs J. Samuel White & Co., Ltd., of Cowes, Isle of Wight.

Fig. 15 gives an illustration of a navy pinnace, 40 feet by 9 feet. This boat was formerly fitted with a steam engine and boiler, and has now got a Thornycroft motor of 80 brake-horse-power using kerosene oil of 150 degrees flash point.

The saving of weight by substituting the oil motor for steam machinery is 4 tons, and the engine room is 4 feet shorter, thus giving increased accommodation.

The British Admiralty are now looking carefully into the question of oil engines of various types with a view to utilizing them instead of steam in all small craft.

The Italian and Austrian Navies also have naval pinnaces fitted with identical motors.

Fig. 16 illustrates a Thornycroft torpedo launch.

FIG. 16.—THE DRAGONFLY. A MOTOR TORPEDO LAUNCH

FIG. 17.—YARROW-NAPIER PETROL TORPEDO BOAT, BUILT FOR THE BRITISH GOVERNMENT BY MESSRS. YARROW & CO., LTD., LONDON AND GLASGOW

Fig. 18 shows two shallow-draught gunboats propelled by internal-combustion engines built by Messrs. Yarrow & Co., Ltd., for the Austrian Government for service on the Danube.

Fig. 19 shows a shallow-draught yacht which was built for use on the extensive inland waterways of Russia. It has commodious saloons and also sleeping cabins, bathroom, etc. The two motors of 50 brake-horse-power each drive twin screws placed in tunnels to facilitate the shallow draught of the boat, and the speed attained was 12½ miles per hour, using Russian paraffin oil as fuel.

The small space occupied by the motors allows for considerably more accommodation than would be possible were steam machinery fitted, and their light weight makes it easy to get a good speed on a light draught.

The vessel was built of steel and constructed in three sections for transport.

Fig. 20 illustrates another motor-driven yacht of 120 feet in length, which has just been completed in Australia. The machinery consists of three sets of 100-brake-horse-power Thornycroft motors driving triple screws. The fuel used is, of course, kerosene. There is also a very complete installation of electric light and electric fans, the dynamo being driven by another small oil motor.

The arrangement of triple screws is specially suitable to yachts or any other vessels which cruise a great part of their time at reduced speed. One or two engines, as desired, can be worked to their full capacity, thus ensuring greater economy than if single or twin screws driven by engines throttled down to below their full power were used for cruising.

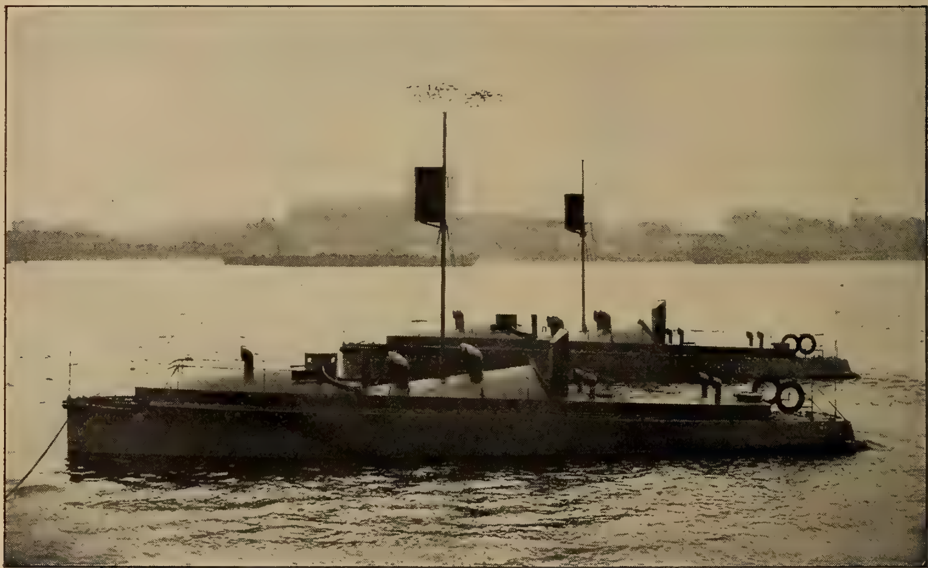


FIG. 18.—MOTOR-DRIVEN GUNBOATS, 60 FEET LONG, 9-FOOT BEAM, CAPABLE OF A SPEED OF 22 KNOTS. YARROW & CO., LTD., GLASGOW

Fig. 21 shows a 60-foot steel harbour launch fitted with a 100 brake-horse-power Diesel engine propelling the boat at a speed of 10 knots. The boat is constructed of mild steel, having straight stem and counter stern, four water-tight bulkheads, fore and aft cabins, steel casings over engine space, teak skylight over forward accommoda-

FIG. 19.—THORNYCROFT SHALLOW-DRAFT MOTOR YACHT SWIETLANA

FIG. 20.—AUSTRALIAN MOTOR YACHT BRONZEWING

FIG. 21.—HARBOUR SERVICE LAUNCH FITTED WITH 100-HORSE-POWER DIESEL ENGINE.
J. S. WHITE & CO., LTD.

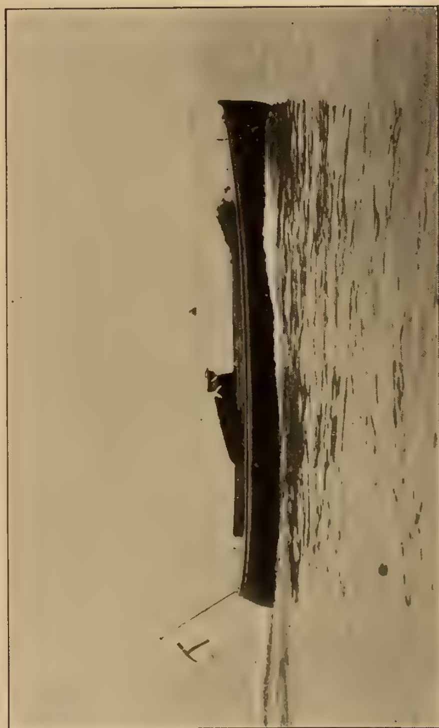


FIG. 22.—THORNYCROFT MOTOR LAUNCH BANZAI

tion, teak deckhouse over aft cabin.

Fig. 22 represents an open launch fitted with a motor. This type has now become the most usual form of small power-driven craft in all parts of the world, and has already completely displaced the small steam launch for sea and river use. No one would now dream of fitting a steam engine in a boat of this kind, so handy and reliable has the small motor proved itself. Absence of smoke and dirt and the possibility of using them without any paid hand has made them very popular for pleasure purposes. As ships' and yachts' tenders they can be launched and got under way at a moment's notice, and for sailing vessels they are a great boon, as they can always tow in case of a calm.

Many yachtsmen prefer to carry a motor launch rather than install an auxiliary motor in the vessel itself, as, besides being able to tow, they can be used in harbour for landing purposes; they are very little heavier than the ordinary rowing boat to carry.

Probably a proportion of the boats of all ocean-going passenger steamers will evenutally be fitted with small motors, as, in case of emergency, they would add greatly to their efficiency.

All the recently built torpedo-boat destroyers of the Swedish Navy have launches fitted with Thornycroft motors.

Two motor launches have lately been completed by Messrs. Thornycroft for H. M. the King of Spain to be carried on the R. Y. *Giralda*. They are 28 feet long, with a beam of 7 feet. Notwithstanding that their proportion of length to beam is very small, and that they were substantially built for sea-going duties, they attained the remarkable speed of over 14 knots. They are twin-screw boats, each propeller being driven by a 30 horse-power motor.

As an example of a modern torpedo boat, we may mention a Yarrow-Napier petrol torpedo boat, built by

FIG. 23.—MOTOR YACHT TRIDENT, BUILT AND ENGINED BY MESSRS. WOODNUTT & CO., ST. HELENS, ISLE OF WIGHT, FROM THE DESIGNS OF MR. ALFRED WESTMACOTT

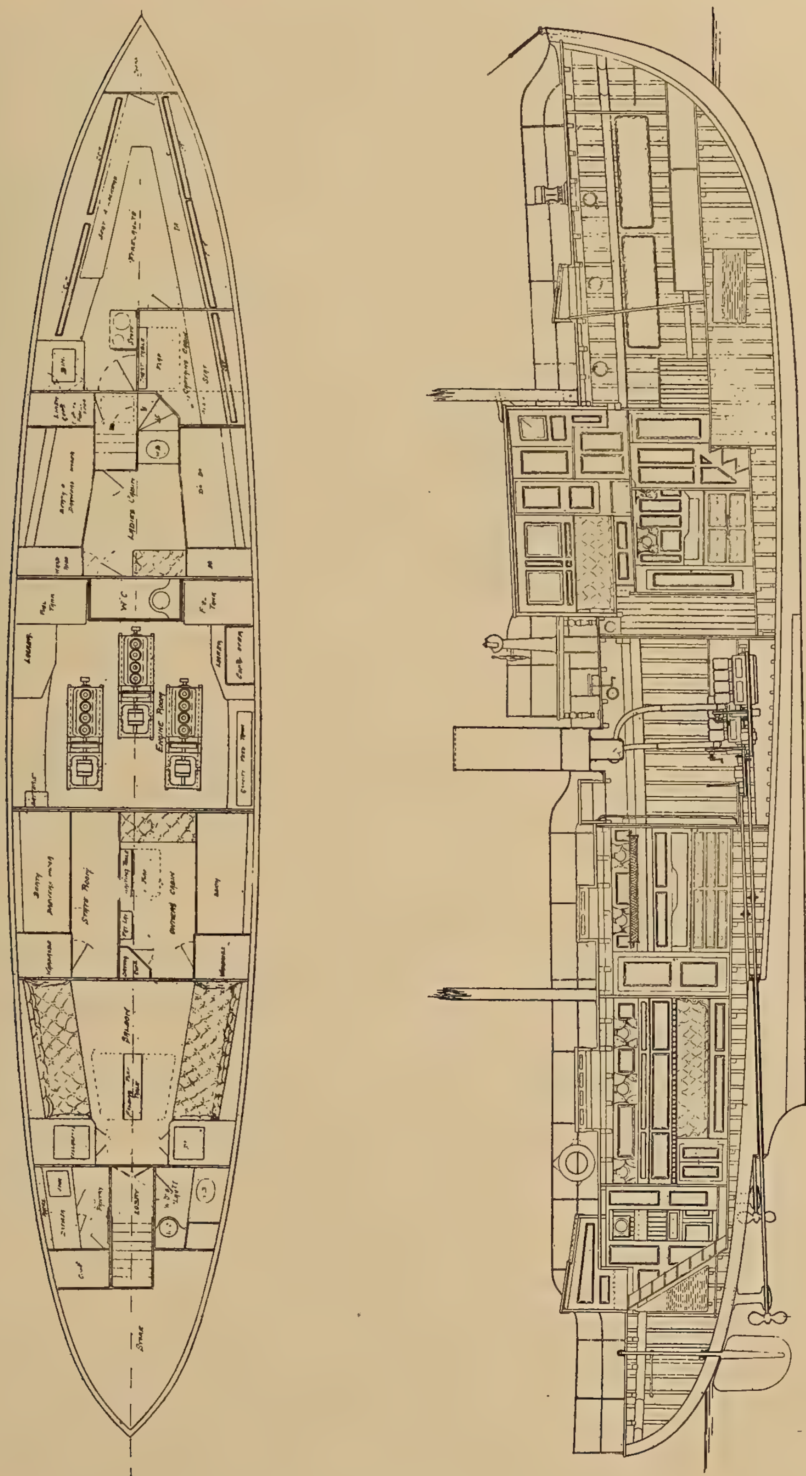


FIG. 24.—PLAN AND LONGITUDINAL SECTION OF MOTOR YACHT TRIDENT. MESSRS. WOODNUTT & CO., ST. HELENS, ISLE OF WIGHT

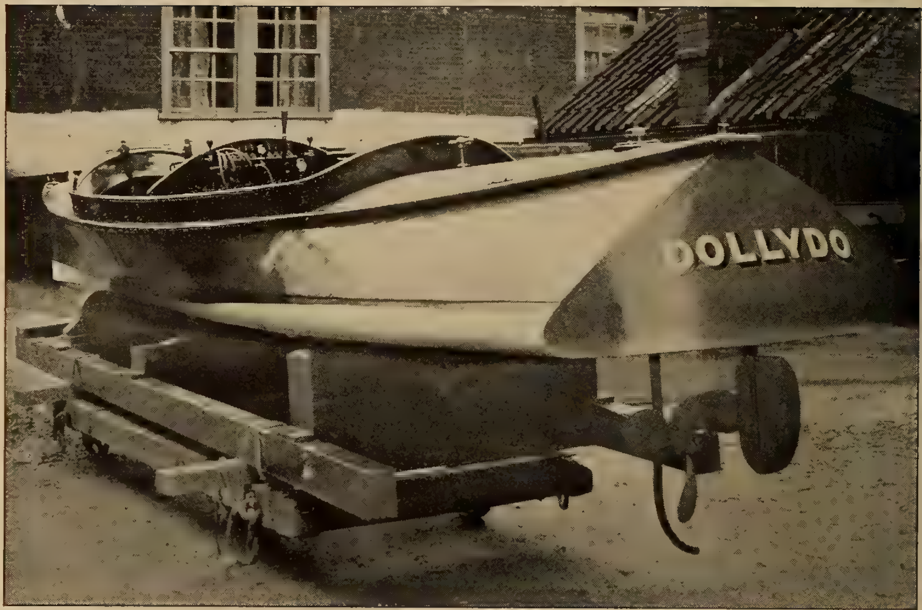


FIG. 25.—STERN VIEW OF THE DOLLYDO. LENGTH, 26 FEET; BEAM, 4 FEET; 20 BRAKE-HORSE-POWER, 4-CYLINDER ENGINE. SPEED, 12.5 KNOTS AT 800 R. P. M. BUILT BY MESSRS. BOULTON & PAUL, NORWICH

Messrs. Yarrow & Co., Ltd., for the British Navy. This boat is shown under Fig. 17. When carrying 3 tons it can attain a speed of 24 knots, and when running light the speed is 25 knots. The radius of action is 250 miles. This boat attracted a great deal of attention during the Cowes Regatta of 1907, and was much admired by King Edward and Queen Alexandria.

A very useful type of harbour or ship's launch is found in the boat built by Messrs. Thornycroft for the Chilian Navy for use of Dockyard officials, which has proved itself very satisfactory and has stood the test of service on the exposed coast of Chili. Some other launches of somewhat similar type have also been supplied by the writer's firm for private concerns on the same coast. It is not possible for large vessels to get alongside wharfs in many of the ports, and the cargo has to be discharged into lighters, which are towed by these motor launches to the shore. Two launches of this design are carried on the Spanish cruiser *Cataluna,* and have been very successful. In the case of all these boats kerosene is used as fuel.

Fig. 25 is an illustration of a motor boat built by Messrs. Boulton & Paul, Norwich.

SUBMARINE NAVAL WARFARE

By G. Laurenti, Major Constructor, Royal Italian Navy

UNTIL recently the principal means for coast defense consisted of artillery and of submarine mines. The development of submarine mines indicated that artillery was not considered sufficient in itself to resist the assaults of an energetic enemy, but that it should be supplemented by the provision of obstacles and concealed dangers. At the present time, however, fixed mines are considered of minor importance, principally because of the deterioration of the electric cables connecting them to the shore. Apart from the rulings of the Hague Conference, the use of mechanical contact-mines may be considered as a partial means of offense, since they act to blockade a squadron within a harbour, or may be employed to make a bay impracticable. They are, however, undesirable as weapons of defense for a military port, since they are dangerous to any vessel crossing their lines, and their recovery is difficult after the termination of hostilities; besides which they are liable to be displaced by currents, and thus become dangerous to neutrals. Floating torpedoes are found unreliable in service, owing to the rapid deterioration of their delicate mechanism, and hence recent efforts have been directed toward the perfection of the submarine boat. Such boats, controllable beneath the surface of the water, according to the movements of the enemy, and carrying on board a number of torpedoes ready for service, now constitute the most effective means for operating successfully against an opponent. The submarine boat may be considered as the arm of ambush *par excellence,* and although in France and England Fulton's early plans for submarine warfare were condemned as savoring of piracy, yet at the present time such methods are considered as entirely legitimate, as leading to success in naval warfare.

The torpedo boat was designed originally as a vessel for attack by surprise, but an experience of nearly twenty-five years has shown that this method is of very limited value. It is folly for a torpedo boat to attack a prepared enemy in broad daylight, while at night it is most difficult to determine the distance and direction of vessels in motion. Recent British trials have demonstrated the difficulty of hitting a target with torpedoes launched from a torpedo boat at night, while submarine boats, attacking vessels in motion and aware of the attack, succeeded in making 80 per cent. of hits.

Boats intended for warfare beneath the surface are divided into two classes, namely, "submarines" and "submersibles," but the precise characteristics of these two classes are not very clearly defined.

In general, the term submarine is applied to a boat having but a small radius of action, while a submersible is one of greater capacity. A more correct basis of difference, however, would seem to be that of the reserve of buoyancy, according to which all boats having but a small reserve, say from 10 to 15 per cent., or less, might be termed submarines, while those with a larger reserve of buoyancy would come under the classification of submersibles. A small reserve of buoyancy renders a boat little adapted for long voyages at the

surface, and hence it is unnecessary to arrange such vessels for a large radius of action, whilst those included under the classification of submersibles, having a larger portion unsubmerged, may be better equipped for a larger radius. Probably a more rational classification is that which describes all submarine torpedo boats as adapted either for coast defense or for high-sea service, corresponding somewhat to the practice obtaining with ordinary torpedo boats.

In addition to the resistance to motion, however, there must also be considered the crushing action of the external pressure. Theoretically the cigar-form of hull is assumed to offer the following advantages:

1. Least resistance to motion under water.

2. Maximum resistance to crushing in proportion to weight.

The first advantage is very materially affected by the presence of superstructures necessarily attached to the

FRENCH SUBMARINE GRONDIN, SHOWING DEPRESSION OF STERN WHEN UNDER WAY

Taking into account first the form of the hull, the conditions involved in ordinary floating operation include simply such lines as give the least resistance at the maximum required velocity, and also furnish the best nautical qualities. For a real submarine, that is, a vessel having but a short radius of action at the surface, and intended principally for operation under water, the form adapted for minimum resistance beneath the surface should be given entire attention, while for submersibles, designed for long voyages either upon or below the surface, both conditions should be carefully studied.

hull, these also affecting the weight and requiring heavier plates than indicated by theoretical computations. In practice, therefore, the defects of the cigar-shaped hull may be enumerated as follows:

1. Large resistance for surface navigation.

2. Tendency to depress the stern, both for surface and submarine navigation.

3. Lack of longitudinal stability in surface navigation.

4. Lack of space for the machinery, especially near the ends.

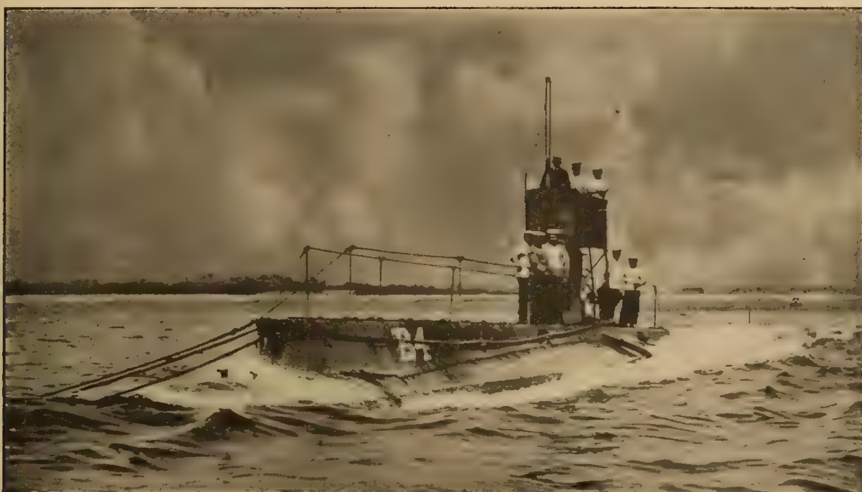
The first defect is due to the waves formed by this particular shape of hull, and for this reason a speed is

soon reached at which the resistance when traveling on the surface is greater than that when moving beneath the water. The second point is really a question of dynamics, due to the fact that the water has a tendency to mount the stern and cause its depression, as is shown in the illustration of the French submarine *Grondin.* This action is modified either by the addition of superstructures, as in the British submarines, classes "B" and "C," or those of *Lake* and *Equivilley,* or by the provision of an initial depression of the bow by means of water ballast, as in the case of the American submarine *Shark.*

This tendency to depress the stern constitutes one of the principal defects of a submarine, and was first observed in the early trials of American submarines, in which it was noticed that the horizontal rudders had to be operated in order to raise the stern. This question was also made the subject of experimental investigation by Naval Constructor D. W. Taylor, in the Government testing tank at Washington.*

The results of these experiments fully confirmed the observations at sea. In consequence Mr. Taylor examined the behaviour of a series of submarine types with vertical bow and stern and found these to give a better longitudinal equilibrium when propelled under water.

The insufficient longitudinal stability at the surface is due to the comparatively short length of immersed surface, as was well shown by Sir William White in his investigation of the loss of the submarine "A 8."†



ARRANGEMENT OF SUPERSTRUCTURES ON BRITISH SUBMARINE B4

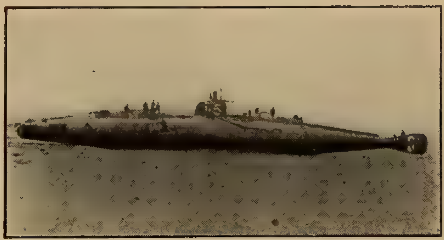
This defect may be eliminated by the use of a braced superstructure, acting to lengthen the hull, but this involves an increase in weight without the addition of a corresponding transverse strength.

By reason of these defects in the cigar-shaped hull, various other forms have been devised, taking into account the requirements both of surface and submarine navigation. Among these, one of the first was that used by the French engineer, Laubeuf, who, in the *Narval* (1896) adopted a mixed construction, consisting of a double hull; the outer

* See: The "Limitation of the Diving Submarine," by R. G. Skerrett, "Journal of the Royal Artillery," June, 1907.

† Report before the Royal Society, May, 1906.

skin being of light plates of a form adapted for surface navigation, and an inner shell with transverse bulkheads to resist the external crushing pressure. This design has advantages, so far as the external form is concerned, and gives additional strength to resist collision, but it has the defect that the space between the two hulls cannot be pumped out at great depths, because the outer shell is too light to resist the pressure.



BRITISH SUBMARINE B5

Since external superstructures are considered indispensable in connection with surface navigation, it has been found possible to utilize them to aid in giving transverse strength, and to use other forms of cross-section than the circular for the hull. In the submarines designed by the author the inner and outer hulls are both used to resist the external pressure, and the superstructure is designed so as to stiffen the upper part of the boat.

The reserve of buoyancy differs very much in boats of different designs, ranging from a minimum of 5 per cent. of the total displacement in some of the French types, about 10 per cent. in the English and American Holland boats, to 20 per cent. in the *Lake* boat, and 30 per cent. in the French diving boats of the Laubeuf types. The nautical qualities of the boat depend very much upon the reserve of buoyancy, and in general, the larger this reserve the better the qualities. For coast-defense submarines, intended to protect bays, harbours and channels, the reserve buoyancy may be allowed as low as 10 per cent., but for boats intended for longer cruising the reserve must be much greater. In some of the recent submarines the reserve buoyancy reaches nearly 60 per cent. of the displacement, thus approximating closely the ordinary torpedo boat, and having nearly as good nautical qualities. In the case of an ordinary vessel the two elements of stability are the reserve buoyancy and the metacentric height. For a submarine, however, it is possible to have a metacentric height suitable for surface navigation, while at the same time the reserve buoyancy may be reduced either to zero or to a minimum of not more than half a ton in either small or large boats. This means that even a small influx of water in a submarine, while beneath the surface, might prove disastrous if not immediately followed by a corresponding lightening.

It would be possible to maintain a greater reserve of buoyancy while navigating beneath the surface if a portion of the motive power were diverted to maintaining the submergence, but this would be at a sacrifice of propelling power, and hence of speed.

FRENCH SUBMARINE OPALE WITH LITTLE RESERVE OF BUOYANCY

Since submarines must be operated under two different conditions, namely, at the surface and beneath the water, it is necessary to have two independent sets of motive-power machinery. As the permissible weight for the machinery has to be divided

between the two portions, the power of each is limited, and this fact alone prevents a submarine from competing in speed with a surface vessel. A high speed, however, is not required for a submarine boat, as it is in the case of scouts or torpedo boats, in which speed is the only arm of defense.

There is at the present time no type of submarine boat combining maximum speed both on the surface of the water and when submerged, and the opinions of engineers are divided as to the relative importance of the two portions of the service.

As examples of recent practice we may note the Italian submersible *Glauco*, of 160 tons displacement, designed by the author, which has a speed of 14 knots at the surface and 7 knots when submerged. The latest type of American Holland boat, with a displacement of 245 tons, has a surface speed of 11.5 knots, and 10 knots when under water. There are certain limitations for subaqueous velocity which do not obtain in navigation at the surface of the water. Among these may be mentioned the effect of sudden changes of direction in the horizontal plane, also the effect of speed upon the visibility of the periscope. The photograph of the trail of a periscope shows the extent to which it is visible at a speed of 8 knots, and under such conditions it is impossible to assume that the position of the submarine could remain unobserved. The periscope is indispensable to conduct an attack with any probability of success, and since the submarine, even at a speed of 10 knots, must necessarily be much lower than the maximum speed of a battleship, it is generally thought better by designers to make the speed below the surface secondary to the safety of the men and the secrecy and success of maneuvres.

AMERICAN SUBMARINE SHARK, SHOWING TRIM WHEN STANDING

The propelling machinery of a submarine for surface navigation is generally thermal, while the propulsion beneath the water is effected by electric power. So far there has not been developed any satisfactory type of propelling machinery adapted for both functions, although various plans have been devised with this end in view.

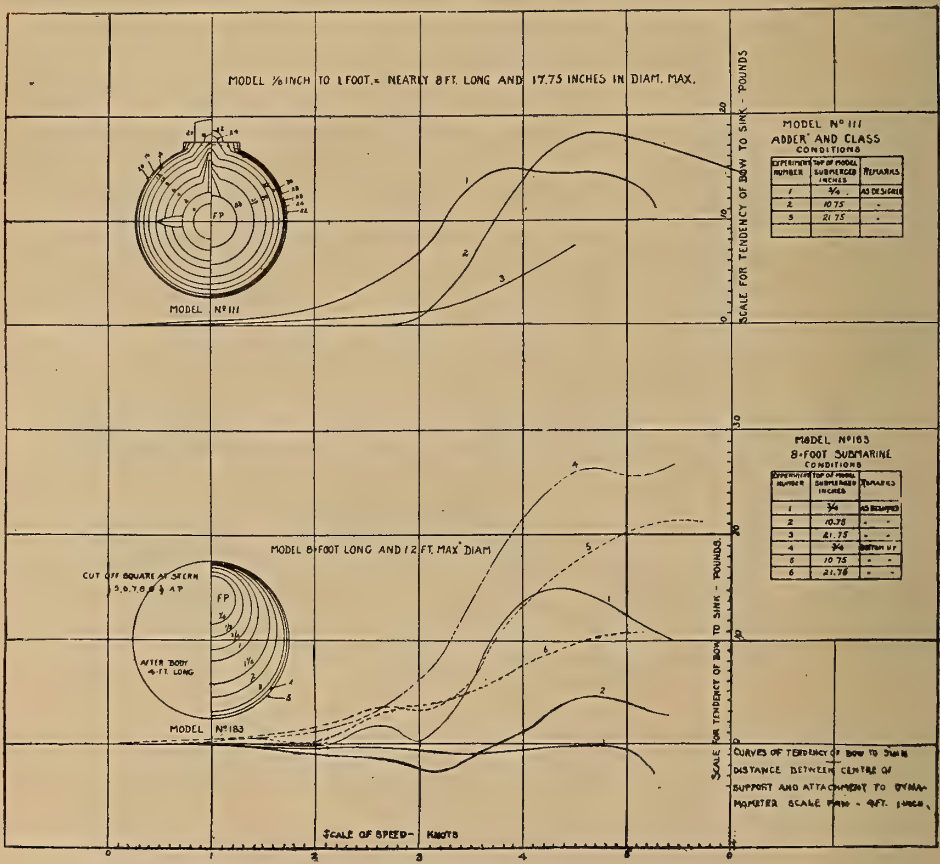
The surface propulsion has been

effected both by steam engines and by internal-combustion motors. In addition to the submarine boats built by Nordenfelt nearly twenty-five years ago, steam power has been employed on some of the French submarines, but these plans have not been reproduced in the latest designs. In the steam-propelled submarines very light water-tube boilers were used, with kerosene as fuel, the steam being used in ordinary reciprocating engines; the steam turbine has not been applied as yet to any submarine. The advantages of steam power lie principally in the flexibility of the engine, and in the ease of reversing, but in a submarine steam is inconvenient on account of weight, space occupied, heat developed and noxious gases produced.

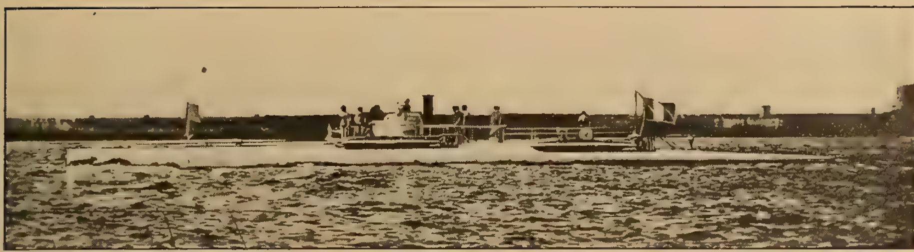
The latest tendency is to use the internal-combustion motor, and although many practical difficulties have been encountered in its application, these have nearly all been overcome during ten years' experience and effort. Combustion motors, as applied to submarines, may be classed under three heads:

1. Motors using a mixture of air and vapour of gasoline or benzine.
2. Motors using a mixture of air and vapour of lighting kerosene.
3. Motors burning heavy oils.

Until recently the motors of the first variety have been most extensively used. Those who have had no



EXPERIMENTAL RESULTS WITH MODELS OF SUBMARINES IN THE TESTING TANK AT WASHINGTON



FRENCH SUBMERSIBLE NARVAL

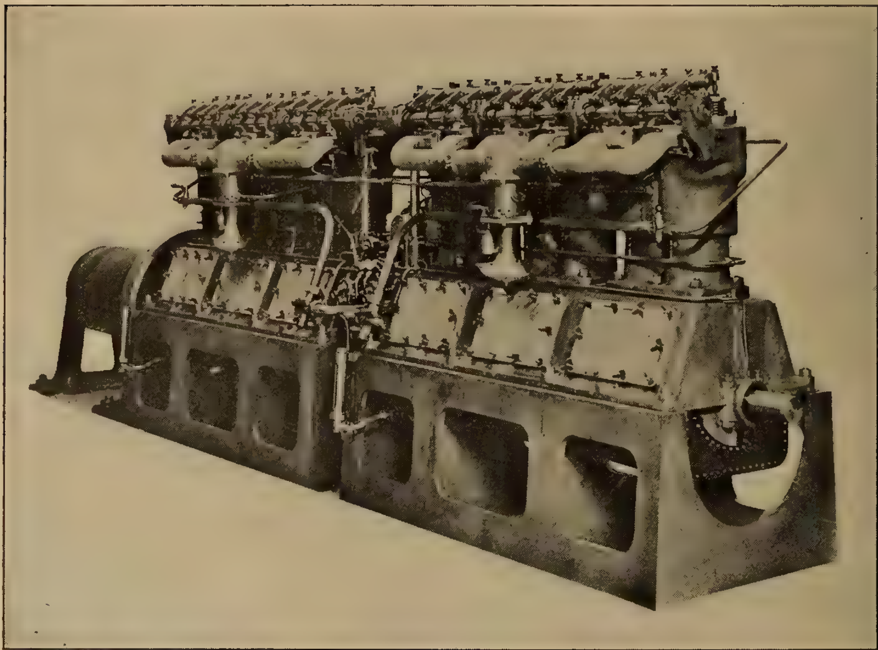
practical experience with gasoline motors in submarine boats have thought such machines objectionable because of the liability of formation of an explosive mixture with the air of the room, but a comparison of the dangers of such motors with those using kerosene will show that the first class is to be preferred to the second. The gasoline motor is more easily started, more easily installed, and is lighter and less objectionable than the kerosene engine. Any danger which might exist from the production of explosive vapours may be avoided by a proper ventilation of the engine room, and experience in a number of British submarines, involving motors up to nearly 900 horse-power, has shown no trouble from this source. The latest types using high pressures, forced lubrication and liberal water-jacketing for cylinders and exhaust pipes have proved very reliable and satisfactory.

Motors using illuminating kerosene in submarine boats may be divided into two varieties, those using a flame vapourizer and those vapourizing the fuel by the heat of the exhaust. An example of the first type is the Gardner motor, used, it is said, in one of the French submarines. The flame vapourizer has the advantage of elasticity, since the operator can regulate the vapourization of the fuel independently of the operation of the engine, but the "bruleurs" are rather delicate pieces of apparatus, and the presence of open flames in a small closed engine room is very undesirable. In the second class may be noted the Koerting and the Thornycroft motors, the former being used in the submarine boats built for Germany and Russia at the Krupp yards at Kiel, while the latter has been used in two submarines built by Thorny-

TRACK OF A PERISCOPE OF A SUBMARINE AT 8 KNOTS SPEED

croft for the Italian Government. The Koerting motor is of the two-cycle type, and in starting the fuel is vapourized by an electric current, and after the engine is started the heat of the exhaust gases is employed. The Thornycroft motor is a four-cycle engine and is started by benzine, the kerosene being used after the engine is well under way, and the heat of the exhaust is available. The objection to this type of motor lies in the fact that the speed cannot be reduced below a certain number of revolutions without reducing the temperature of the exhaust to a point where the vapourization of the fuel is not properly effected. Such engines also require water injection in the cylinder in order to permit the use of a high compression without premature ignition, and unless distilled water is used the durability of the motor is apt to be affected. Such engines require more attention than the gasoline motors and the consumption of fuel is somewhat higher.

Better results are obtained by the use of the Diesel motor, burning heavy oils, especially in connection with the two-cycle Diesel motor built by Sulzer Brothers. The first submarine in which the Diesel motor was used was the French boat "Y," and some difficulties were encountered because of the conditions under which the engine had to work. In the later French submarines of the *Topaze* type and the submersibles of the *Pluviose* type, the Diesel motor of the four-cycle design has been employed with success. The two-cycle type of Diesel motor, however, is the latest design, and in some of the recent Diesel engines built by the Nuremberg Maschinen Fabrik, the weight has been reduced to 12 to 15 kilogrammes per effective horse-power, or about the same as a benzine four-cycle motor running at the same speed. The great advantage of the Diesel motor lies in the fact that it is able to burn all kinds of heavy oils up to a density of 0.9, thus giv-



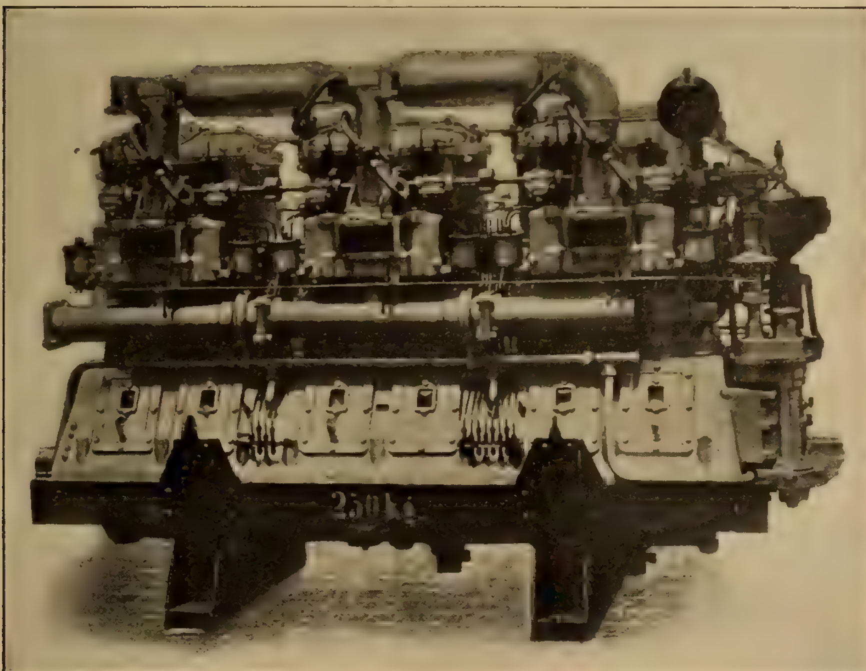
FIAT GASOLINE MOTOR OF 300 BRAKE-HORSE-POWER AS ARRANGED FOR SUBMARINE

ing the greatest security against fires and explosions, while, at the same time, it is ready to start at any time, and requires no preliminary heating of the fuel.

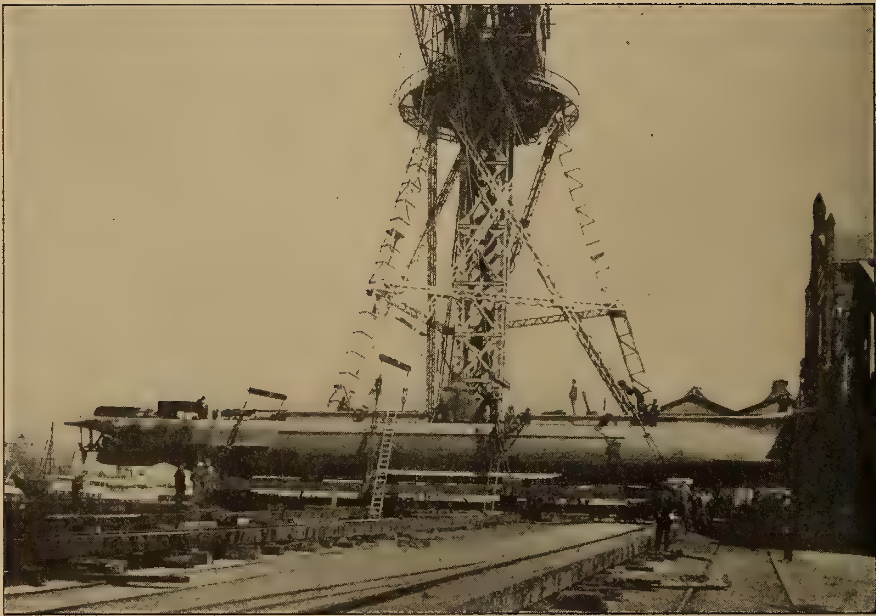
In designing a heat motor for use with a submarine, its relations to the electric machinery used for navigation below the surface must be considered.

The modern tendency is to arrange the two motors on the same shaft, without the interposition of any gearing or other intermediate mechanism. In order to permit the two motors to be operated, each to the best advantage, the plan of using a propeller with adjustable blades, controlled from the interior of the boat, is employed in the later submarines, the Meissner propeller being an example. Screws of this sort have not, as yet, been used above 300 horsepower, but there appears to be no reason why this should not be exceeded. In the case of some small submarines, of which the French type *Naiade* of 68 tons is an example, electric power has been used, both for the surface and submarine propulsion.

All the submarine boats now in service use electric power for propulsion beneath the surface. Some of the earlier boats, such as the *Plongeur,* of Bourgois and Brun, made in France in 1863, used compressed air both above and beneath the surface, while the Nordenfelt experiments in Sweden and in England in 1884-1885 used a steam engine for both purposes. Recently some attempts have been made to use the internal-combustion engine for motive power when submerged. In France, in 1904, the submarine "Y" was launched, according to the designs of Bertin, and equipped with a Diesel motor, supplied with compressed air from tanks when operating beneath the surface. Tests with this apparatus, however, did not warrant a continuance of the system, and



KOERTING PARAFFINE MOTOR FOR SUBMARINES, 125 BRAKE-HORSE-POWER



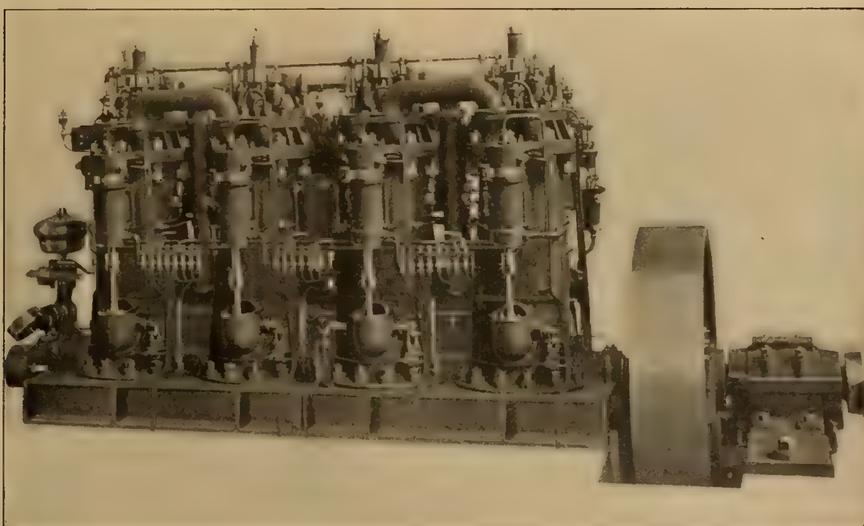
A KRUPP SUBMARINE, D'EQUEVILLEY TYPE

this boat has since been equipped with electric power for submarine service. More successful experiments have been made in Russia with the Drezwiecki system. In this case a small boat, provided with a benzine motor, was operated for more than an hour beneath the surface, and no serious inconvenience from heat or foul air was reported, but the noise was found objectionable. The visibility of the exhaust discharged below the surface of the water is a defect of this system, but this is not of serious importance if the water is even slightly rough. The French engineer Sabathe has proposed to operate the Diesel motor upon a closed cycle, the engine drawing in its own exhaust gases, together with

THE BRITISH SUBMARINE A11 WITH NEW TYPE OF CONNING TOWER

sufficient oxygen to burn the fuel charge, so that the volume of exhaust gases is greatly reduced, and the perfection of combustion would result in the production mainly of carbon anhydride, almost wholly soluble in water, and thus give an invisible exhaust.

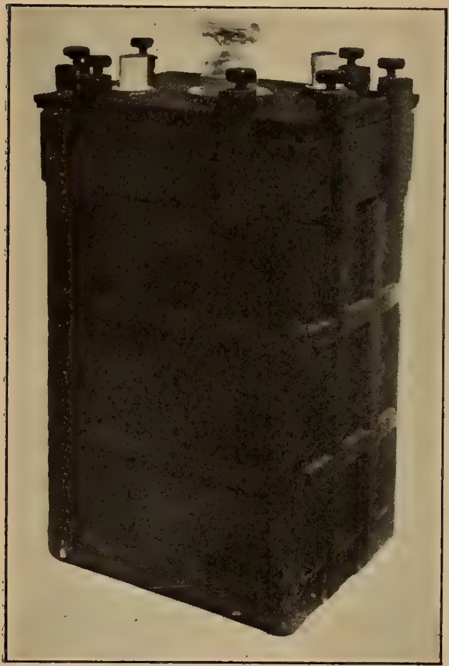
The Italian engineer Del Proposto has devised another type of propelling mechanism, which, it is understood, is to be installed in a large submarine soon to be built for the Russian Government. The system involves the use of two Diesel four-cycle motors with four cylinders each. During navigation on the surface one of these motors is used to compress large volumes of air to a high pressure in suitable storage tanks. During operation beneath the surface, one of the cylinders of the Diesel motor will be operated by compressed air, the exhaust from this cylinder being discharged into the engine room for the purification of its atmosphere, and also being drawn from thence into the other cylinders during the suction strokes, these cylinders operating as a combustion motor. It is practicable to proportion the parts so that an equilibrium of action may be obtained on this principle, and at the same time obtain a greater power when navigating below the surface than when above, the two speeds thus being almost equal. When very near the surface, as when about to discharge a torpedo, any visible exhaust may be avoided by operating all the cylinders of the Diesel motor with compressed air, the exhaust being delivered into the engine room. Since it is possible for men to support a pressure of nearly four atmospheres without serious inconvenience, it would thus be practicable to operate a submarine for several miles at high speed without revealing its presence. It is understood that it is only by the use of some form of combustion motor beneath the surface that high submarine speeds can be attained; Del Proposto expects to reach a speed of 15 miles per hour.



DIESEL FOUR-CYCLE MOTOR OF 140 BRAKE-HORSE-POWER, ARRANGED FOR SUBMARINES

The principal difficulty with electric power in submarines appears in the weight of the storage batteries and the space required for them. The lightest batteries now used by submarines weigh not less than 40 kilo-

grammes per horse-power when operated at high rates of discharge. A lighter weight per horse-power may be obtained with slower discharge, but the total power available will be reduced. The capacity is always limited, and it is hardly practicable to operate a submarine more than three or four hours under water at full speed. Nevertheless electric power offers many advantages for submarine use, among which may be noted the following:



ELECTRIC ACCUMULATOR FOR SUBMARINES (LAURENTI TYPE)

1. Uniform weight during the entire period of operation; a feature of much importance in submarine navigation.

2. Quietness during operation.

3. No heat developed, and no deterioration of the atmosphere when the apparatus is properly managed.

4. Ease of subdivision of power for the operation of motors for pumps, fans, etc.

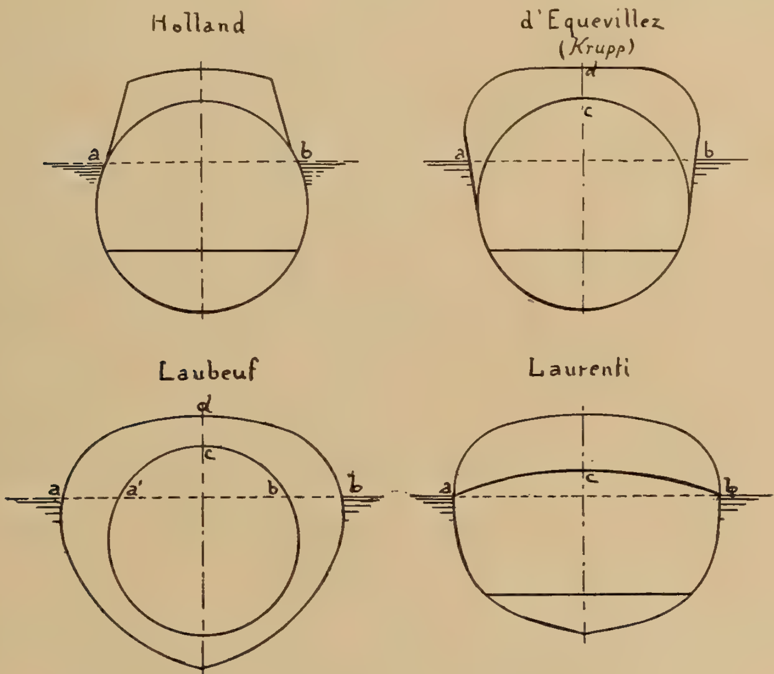
The electric motors used in submarines are of the multipolar type, with either compound or derived windings. Except in some special instances, the motors operate at uniform speed with constant current, the variability of speed, about 15 per cent., being obtained by means of a resistance interposed in the field. For greater speed variations it is usual to vary the voltage by subdivision of the batteries; operating the sections either in series or in parallel as may be required. The minimum voltages used for operation in parallel are from 100 to 200 volts, and for series operation from 200 to 240 volts. Above 200 volts, however, it is difficult to maintain satisfactory insulation, and hence in the latest designs it is planned to maintain the voltage uniform, as 100 to 200 volts, and use motors with compensation poles, thus permitting speed variations from 1 to 1/5. This involves a somewhat greater weight for the motors, but the advantages are sufficient to permit this.

When two forms of motive power are employed, the heat motor is used to charge the batteries, and boats thus equipped are termed "autonomous" because they do not require special charging stations. The accumulators employed are generally of the ordinary sulphuric-acid type, with Faure negative plates, and either Planté or Faure positives. Batteries of the Edison type, with alkaline electrolyte, and plates of nickel salts appeared to offer many advantages, but they have not proved satisfactory. The accumulators form an important portion of a submarine, and constitute a large part of the weight of the machinery, and when cared for with intelligence and judgment they give very satisfactory results. In the French submarines the batteries are generally of the "Fulmen" type, using d'Arsonval positive plates; the English boats use the "Chloride" type; the German and Russian are equipped with the batteries made by the Hagen Accumulatoren Fabrik; while the Italian submarines use the

accumulators made by the *Societa Generale Italiana Accumulatori Elettrici,* which is a branch of the Hagen works.

In general the batteries are made with ebonite cells, some hermetically sealed, others not sealed, the acid being carried at such a level as not to be spilled by the rolling of the boat. In order to avoid inconvenience from the motion of the electrolyte in the cells, a special form of Hagen battery has been made under the Krupp patent with an absorbent material between the plates to take up the excess of liquid. In order to secure a reduction of weight, some recent batteries have been made with both the positive and negative plates on the Faure system, and this will prove satisfactory if the positive Faure plates prove as durable as those on the Planté system.

The principal difference between the batteries in the various types of submarines appears in the sizes of the elements, the shape of the cells, and the method of removing the gases which are evolved. In the British and American submarines of the Holland type, as well as in the Lake boats, and in some of the Russian boats, elements of large size and weight exceeding one ton have been used, while in the French boats the weight is about 200 kilogrammes, and in the Italian submarines about 100 kilogrammes. The object of using large elements is to obtain the greatest capacity with the least weight, but there are a number of objections to such a practice. Thus, large elements are difficult to instal, and have often to be made in several parts to permit them to be passed through the hatches; besides which it is difficult to replace damaged parts. With large elements, also, any damage puts a considerable portion of the entire battery out of service, while the contrary is the case with smaller elements.



CHARACTERISTIC CROSS-SECTIONS OF SUBMARINES

An important matter is the removal of the gases which are evolved from the battery, especially during the latter part of the period of discharge. As is well known, these gases consist of oxygen and hydrogen in such proportions as constitute an explosive mixture, besides being non-respirable, and a number of serious accidents have occurred by their accumulation. Owing to the acid vapours carried off with the gases their escape produces injurious corrosion of the machinery, and hence their removal is a matter of importance. Several methods have been employed for dealing with this difficulty. If the cells are not hermetically sealed, a method followed in the French boats, and in those built by Krupp, the gases escape into the boat and are drawn off by the use of electric exhaust fans. This plan is objectionable because the air of the boat is vitiated and because it is not possible to insure the clearing of all parts of the vessel. Another plan, used in the Holland and the Lake submarine boats, consists in enclosing the cells in a large case, from which the gases are drawn off by a ventilating fan. This is an improvement over the first method; but it is not altogether safe, as there is a possibility of the explosive mixture in the enclosing chamber becoming ignited from a spark from the electrical apparatus. A third plan, introduced by the author in some of the Italian submarines, consists in sealing each cell air-tight and providing it with a vent hole and tube, the several tubes all being combined into one collector which is exhausted to the exterior of the boat. During the charging of the battery, sufficient air enters through the main collector to change the composition of the mixed gases and produce a non-explosive mixture. This system has been found successful in practice, and in no case has an explosion ever occurred.

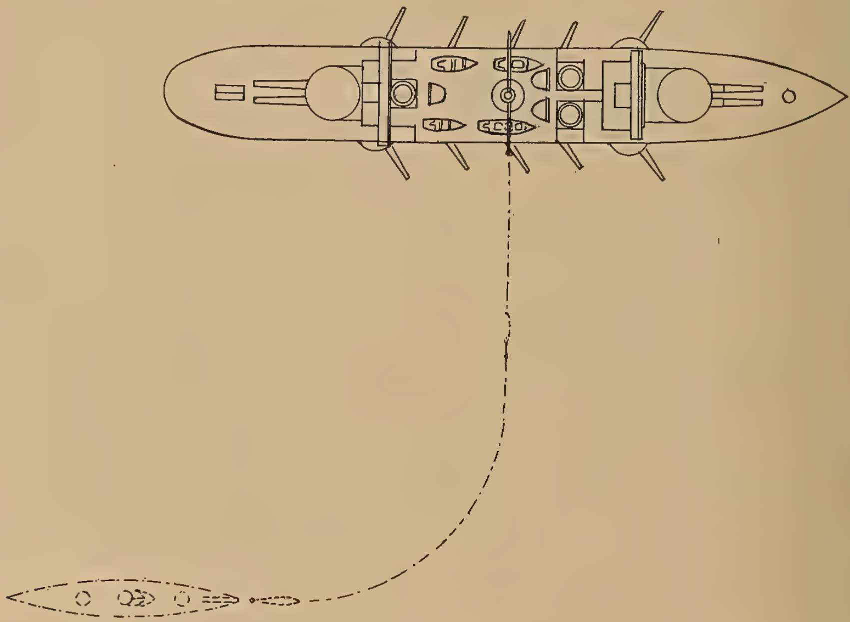


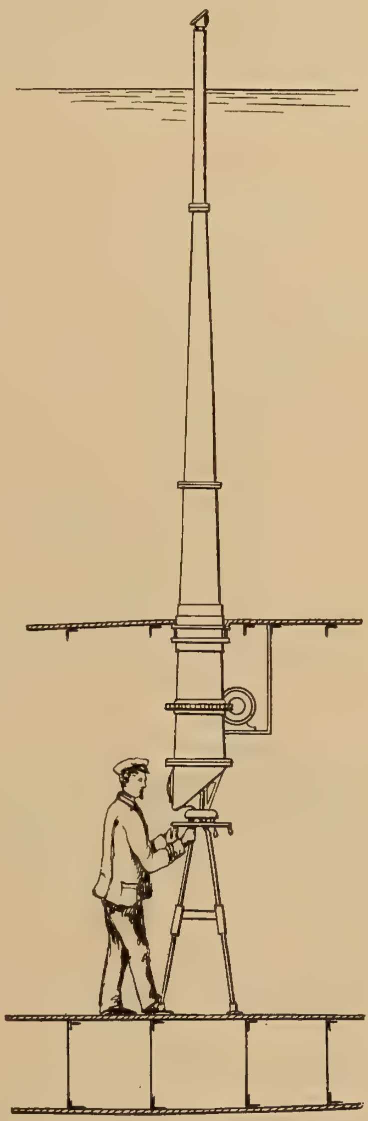
DIAGRAM ILLUSTRATING PATH TAKEN BY A TORPEDO, AUBRY SYSTEM

Submarine navigation is the principal function of submarines and sub-

mersibles, and to it the greatest attention must be directed. Three problems are involved in successful operation: (1) the vertical movement; (2) horizontal navigation at a pre-determined depth, and (3) maintenance of a required stationary position.

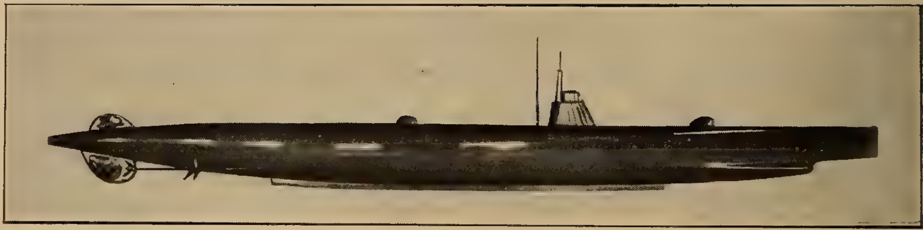
The volume of a floating hull may be divided into two parts: the immersed portion, displacing a quantity of water equal in weight to the weight of the entire vessel; and the portion which is above the water-line, which, being water-tight, constitutes the reserve buoyancy. If the entire body is to be submerged it is necessary to overcome the reserve buoyancy, and this may be effected in two ways. The reserve buoyancy may consist entirely of a chamber distinct from the interior of the boat, in which case the water may be alowed to enter, simply by putting it into communication with the sea. If a portion of the reserve buoyancy is included as a part of the interior of the boat, it is necessary to increase the weight of the hull by admitting a corresponding amount of water ballast. In the diagram, sections are given of four different types of boats, and in each the reserve buoyancy is indicated by the space *a, b, d, a.*

In the Laubeuf system the submersion is effected by putting the space between the two hulls in communication with the sea, while in the other boats a double bottom is provided, the filling of which causes the vessel to sink. In the Holland and the Laurenti boats the superstructure is entirely above the hull, so that it fills or empties automatically as the boat sinks or rises; in the other designs the superstructures must be emptied mechanically, or by compressed air. The reserve of buoyancy may be just overcome, so that the hull weighs exactly as much as the volume of water which it displaces, or the reserve may not be entirely overbalanced, but a small amount, generally about half a ton, allowed to remain, so that the boat has a tendency to rise, or there may be an excess of ballast added, and the vessel has a tendency to sink.



RUSSO-LAURENTI CLEPTOSCOPE

The horizontal path of the boat is controlled by horizontal rudders, generally arranged in pairs on both sides of the hull and connected to the same shaft. In the earlier boats only one



MODEL OF ITALIAN SUBMARINE, LAURENTI TYPE

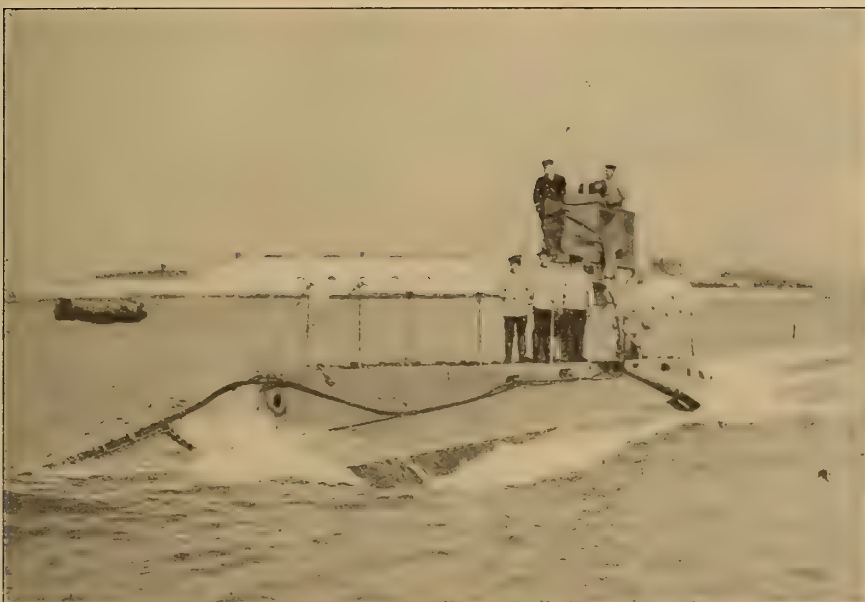
pair of rudders was used at the bow or at the stern, but in modern practice two pairs are employed, one pair at each extreme end. In some cases the stern rudders are held at a fixed angle, and the steering effected only by those at the bow, but in other designs both sets of rudders are connected, so that they are operated together.

The behaviour of a boat beneath the water is affected by a number of elements, including the metacentric height, the size and position of the horizontal rudders, the form of the hull, and the positions of the total resultants of the propelling and resisting forces. At the present time it cannot be asserted that any particular form of hull is best adapted for submarine navigation. The investigations of Taylor in the Government testing tank at Washington have not as yet given positive results, and when we consider that after many centuries of surface navigation new forms of hulls are developed, improving on the preceding ones, we may also expect a continual development in the form of submarines.

The real purpose for which a submarine is designed is the delivery of torpedoes against the enemy, and while the greatest care should be given to this feature, it is often overlooked by the designer. At the present time there is a difference of opinion as to whether it is better to have a number of external tubes from

THE ITALIAN SUBMARINE NARVALO

which torpedoes may be released at the proper moment, or whether internal tubes are to be preferred, from which the torpedoes may be discharged with an initial impulse in a determinate direction. In the case of the external launching tubes or cages, either rigid or swivelling, such as the Drzewiecki, the torpedo leaves the tube by the action of its own propeller, and for this reason its initial velocity is very low, and hence it is not well controlled by its rudder, so that the number of hits with this cage. The objection has been urged against the internal tube, that it is impracticable to carry as large a number of torpedoes on board of a submarine as in the external cages, and that it is not practicable to discharge a torpedo at right angles to the hull, because of the insufficient width of the boat to carry cross-tubes. From a military viewpoint, however, it is better to have a few torpedoes accurately discharged than to carry a number in unreliable cages. So far as attack at right



BRITISH SUBMARINE C7, SHOWING SUPERSTRUCTURE

system is small. It is also found that torpedoes carried in cages outside of the hull of the submarine are apt to become injured and are often found in bad condition. In the case of the internal torpedo-tube the torpedo itself is protected, and being given a powerful initial impulse by compressed air, it starts off in the intended direction, even if its own propeller has not yet begun to act. Experience has shown that it is much easier to hit a mark with the internal tube than by the use of the external angles is concerned, this can be effected by the use of the Aubry system, in which the torpedo itself turns in its path. In the use of this system, with the Italian submersibles of the author's design, much success has been attained for several years, the torpedoes making an accurate turn of 90 degrees from the direction of discharge, in a curve of about forty metres radius, as shown in the illustration on page 254.

In the small French submarines the rigid cage, fixed in the direction of

EARLY TYPE SUBMARINE HOLLAND NO. 3

the keel, is used, while in the larger boats the swivelling cage, on the Drzewiecki system, has been adopted. In all other navies the system of internal torpedo tubes is employed. In order to enable a single tube to discharge several torpedoes, the Electric Boat Company, builders of the Holland submarine boat, have designed a form of revolver, there being a rotary chamber containing several torpedoes which may be successively brought into position and discharged. When there is but a single torpedo tube it is generally placed at the extreme bow. This arrangement is defective, because any slight collision is apt to damage the tube, or possibly cause the torpedo itself to be discharged, if one is in the tube. For this reason the author has placed the tubes in the boats of his design at some distance from the prow.

The first submarines were blind, and it was not until 1902 that satisfactory appliances were perfected for vision when submerged.

The earlier navigation was conducted by rising to the surface at frequent intervals to make observations as to direction. Now, however, there are a number of satisfactory visual appliances, among which may be mentioned the Ipoidroscope of Howard Grubb, the Telops of Triluzzi, and the Russo-Laurenti Cleptoscope. Each of these devices has its own special features. The Cleptoscope has the advantage that it may use an ocular of 20 centimetres in diameter, and with such a large lens it is possible to cover a field of nearly 50 degrees, objects being seen of natural size, using both eyes without fatiguing the vision and permitting the navigation to be conducted as effectively as with any other type of vessel. Attempts at direct vision through the water have been abandoned, since it has been found impossible, even with optical instruments, to see further than 10 to 12 metres in clear water. This is probably due to defects in human vision, which seems to be different from that of aquatic animals.

Although the commander of a submarine sees what is above his vessel, he cannot see beneath it, and hence it

is important that he should be familiar with the nature of the bottom. It is impossible, however, for him to perceive the movements of another submarine in his vicinity, and hence it would be imprudent to send several submarines into the same waters without limiting closely the zone of movement of each boat. The success of recent experiments in the transmission of sound under water has led it to be considered as a method of signalling between two submarines.

The smallest diameter of a good periscope, or rather that portion of it which projects above the surface of the water, is about 10 centimetres, and this is hardly perceptible from a neighbouring vessel, and its motion cannot be seen until the speed of the boat reaches about 6 knots, above which speed, as we have seen, the ripples might indicate the position of the submarine.

It is generally assumed that the air contained in a submarine is capable of sustaining life for but a very short time, and many inventors have endeavored to devise systems for the regeneration of the air. Such systems have not proved successful in practice.

It is understood that the amount of carbon anhydride in breathable air should not exceed 1.5 per thousand, while the normal proportion is 0.4 per thousand. This means that for each person there is required nearly 20 cubic metres of fresh air per hour. This is too great a demand for the capacity of a submarine, but in practice such a quantity is not found to be necessary. It is found that strong and healthy individuals experience little inconvenience in air containing as high as fifteen parts of carbon anhydride per thousand, and that when this limit is reached it may be partially renewed by the admission of a small amount of fresh air from storage compression tanks, with the removal of a corresponding portion of the foul air, this latter being pumped from the lower part of the boat. The possibilities of surviving in contaminated air are shown in the case of the *Farfadet,* where six men lived for 36 hours in a space of only a few cubic metres' volume contaminated by acid vapours from the accumulators.

The mechanical problems involved in submarine navigation for warfare may be considered as solved, and it only remains for the details to be perfected by actual practice in serv-

BRITISH SUBMARINE A-VI., NAVIGATING AT THE SURFACE

ice. It must not be forgotten that in such a complex and highly organized apparatus much depends upon the men by whom it is operated, and that if the best results are expected from such a piece of mechanism it must be placed in the hands of men of the highest ability. Such men have never been lacking in any civilized nation, and unfortunate accidents have disclosed true heroes in the service of the submarine. Thus, by the union of the intelligence of the men who have designed the mechanism and the skill of the men by whom it is operated, the world is in the possession of an apparatus to which, in the near future, the coast defense and security of any nation may well be confided.

Photograph by Burr McIntosh

JESSE MERRICK SMITH

PRESIDENT AMERICAN SOCIETY OF MECHANICAL ENGINEERS

(See Page 356.)

CASSIER'S MAGAZINE

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FLOATING AND FLYING NAVIES

THE MILITARY VALUE OF AERIAL NAVIGATION

By J. C. Bayles, M. E., Ph. D.

A DISCUSSION of great interest occurred a few evenings ago at a dinner given in New York at the house of a gentleman whose hospitality is distinguished by the skill with which he brings together those best calculated to make his dinners memorable. He is himself known to his friends as the Professor. The guest of honour on the occasion referred to was a well-known naval officer of high rank, whom we will designate as the Commodore, although his real rank is that of Rear-Admiral and his duties at Washington have to do with construction and equipment in a very important way. Among the other members of the company were an engineer of international reputation, a retired army officer with the rank of Colonel, a judge of one of the Appellate Courts, a distinguished clergyman, three or four business men prominent in the financial world, and a few others—in all about twelve.

The conversation had covered a wide range of topics of no especial consequence until the coffee was reached, when the Engineer focussed it on what is, perhaps, the most interesting question now engaging the attention of thoughtful people by saying to the Professor, at the head of the table:

"Professor, you are wise in such matters; I wish you would explain to me the dispatch from London a few days ago to the effect that the British Government is making preparations to negotiate a loan of five hundred millions of dollars on 'nominal terms' to pay for such an increase of her navy as will maintain it at the two-power standard for several years to come. Now what I should like to know is how, for such a purpose and in our present state of civilization, so considerable a sum of money as five hundred millions can be raised at all unless by confiscation, and especially how, if it is borrowed, it can be had on nominal terms, which I assume to mean for an indefinite period of years and at a rate of interest below that which money commands in safe employments. It has been my experience in connection with public utilities and other large operations that the lender is reasonably careful to make sure that what his money pays for is likely to be useful and profitable. How he can possibly feel this in connection with a fleet of warships I do not understand. To use a fa-

vorite phrase of the late Mr. Cleveland—whose style, if rotund and full-bodied, was one which most of us might imitate with advantage to English literature—'I find it difficult to resist the conclusion' that, as securities, warships are, as the Scotch would say, kittle cattle. Frankly, I never look at one of those over-organized, super-complicated steel bubbles that I do not recall with a smile the comment of a marine underwriter on a vessel concerning which I made inquiry, that he 'would not insure her from the Battery to Sandy Hook with a cargo of shavings.' What, in your judgment, will be the scheme of finance employed in floating a loan so seemingly impossible?"

"I have no idea," answered the Professor, "how it will be done; but in any case I doubt if the intrinsic value of a navy would have anything to do with the success of such a loan. The real security is the faith and credit of the nation, pledged to sustain its naval prestige. A warship is no more unstable security for a bond issue than gunpowder and projectiles; but when gunpowder and projectiles are needed, or deemed necessary, no great trouble is experienced in finding the money to purchase them. Without any knowledge of the British treasury policy, save as it is indicated by the recent change in the patent laws, which promises to add something like $125,000,000 a year to the national wealth, I can imagine that such a loan as you mention might very well be negotiated on the whispered assurance that America and Germany will indirectly pay it."

"Well, there's something in that," answered the Engineer; "but suppose America and Germany do not think the expenditure of $125,000,000 a year on patent protection in Great Britain as cheap as some form of tariff reprisal which will make her little stroke of unneighbourly thrift cost England two for one? Such things have happened to upset treasury plans; the present generation of jingoes and tradesmen would then have the benefit of the two-power navy and posterity may pay the bill, or repudiate it, as may happen."

"Exactly."

"Well, it seems to me that this is treating posterity very shabbily. How would you feel if called upon to pay for your great-grandfather's dead horses? The best warship which can be designed will not be a year afloat before something occurs to make her obsolete. Indeed, her builders will be lucky if this does not happen before she is launched. Besides the perils of the sea, the dangers of show evolutions, of which we had an illustration in the Channel a short time ago, there is a steady and startlingly rapid scientific progress along lines which threaten to make relatively slow-moving, heavily-armoured warships useful chiefly for naval pageants and friendly visits. Am I not right, Commodore?

"I shall be better prepared to answer when I have heard what you have to say in support of your very general statements, with which at present I should find myself quite unable to agree."

"Excuse me, Commodore. Perhaps I was a trifle premature in asking your opinion. I have views on the subject which seem to me to warrant my conclusions—as an engineer, I mean—which may very well be at variance with those of a naval officer. But what's the use? Suppose we talk about something more cheerful."

"As you please; but I should be much gratified to hear a plain statement of your reasons for believing that naval armaments are as futile as you seem to consider them. Those of us who have specialized sharply and know only one line of work might very well derive instruction from one who, like yourself, has a reputation like that of Sir Philip Sidney, of whom it was said that he was educated not in one art or science, but in the whole circle of the arts and sciences."

At this ample compliment a smile went round the table, and there was a chorus of invitation from the company that the Engineer would give his reasons for his very pronounced views. To this the Clergyman added:

"The question of vast and costly naval preparations is so closely related to that of world peace, which is now engaging the attention of Christian men everywhere, that few subjects have greater present interest for the student of human development. If your belief that navies are obsolete and practically useless rests upon a substantial basis of scientific facts, I should deem it your professional duty, my dear sir, as well as your duty as a public-spirited citizen, to make them intelligible to those like myself who are supposed to have some influence in shaping public opinion from the pulpit and in the literature of the Church. I concur cordially with the Commodore in asking you to tell us, as an engineer, why the usefulness of the warship is so near an end."

Thus challenged, the Engineer realized that he must talk or lose prestige. So he opened his mouth and spake, as follows:

"There is nothing new, and should be nothing surprising, in what I have suggested. The same line of thought is engaging the attention of serious-minded men all over the world——"

"Especially inland," ventured one of the company.

"Perhaps so, because inland the traditions of the sea have not taken so deep a hold upon the popular imagination. But, as I was about to say when interrupted, multitudes of wise men, even in seaboard countries, are thinking as I have spoken.

"In my judgment, the future of floating navies will remain a matter of intelligent doubt until we have determined more fully the possibilities of flying navies. You probably noticed, Commodore, that twenty-two of the powers represented in the last Peace Conference at The Hague refused to subscribe to, or even seriously to consider, a resolution agreeing to prohibit for a considerable term 'the discharge of projectiles or bombs from balloons or by other new methods.' To my mind, this was extremely significant. That the resolution was not fully understood, in view of the very interesting recent work of the German air navigators, is at least improbable. Probably to ninety-nine in the hundred of those who heard the resolution read it meant but one thing.

"The uses of balloons have been fully discussed by students of war problems everywhere. A consensus of expert military opinion would show that the airship of whatever pattern is regarded by military commanders as chiefly valuable for purposes of observation. For other military purposes on land it is not now, and never has been, taken seriously. Am I right, Colonel?"

The gentleman addressed, a retired officer of the army who had begun at West Point nearly half a century ago, promptly replied:

"That is my opinion, and I believe it to be the opinion of most army men. It is well understood that a bomb filled with a high explosive and dropped among massed troops would do much damage and involve some loss of effective strength. But in practical military operations troops are rarely massed near the enemy, and the most energetic fusilade from the sky which could be expected would do very little damage to the 'thin red line' of field formation. That any form of airship now known could get far enough away from its base seriously to menace an enemy's country does not seem probable. The service would not be worth the risk. Dropped into a fortification like some of those built in the seventeenth and eighteenth centuries, and even into some of those of later date built for coast defense, a high explosive would probably do a great deal of damage; but not more so than a bomb from a mortar or an explosive projectile of any other kind. Besides, there are

very few fortifications of this character which could be approached by a balloon or airship from land near enough to menace them. If they could be destroyed, the results would be unimportant from the military point of view, since they are chiefly useful as show-places and comfortable homes for idle garrisons. In modern war the earthwork, which can be thrown up in a night, and, if necessary, abandoned the next day, is at once more useful and more formidable than stone walls. Nothing very important would result from dropping a bomb behind an earthwork. In a word, military commanders have no nervousness about what might happen in land operations as the result of aerial attack. Bullets are much more deadly than bombs."

The Engineer, who had expected assent at most, hastened to recover the floor. Continuing, he said:

"I fully agree with the Colonel. The commander of land forces has no other reason to apprehend danger from flying machines of any kind than the revelation of his movements and the exposure of his points of weakness and susceptibility to attack. But with the naval commander the case is, or should be, different."

"The Commodore does not appear to have lost flesh from this cause," remarked a young man, who might have shown greater wisdom by keeping quiet. The Engineer paid no attention to him, but continued:

"In my judgment, the real significance of the recent more or less successful ventures in aerial navigation, so far as national defense is concerned, has apparently been overlooked—unless by those whose official duty it may appear to be to maintain discreet reticence on the subject. These tests suggest, if they have not yet fully demonstrated, that the flying ship has reduced, or promises soon to reduce, the floating ship to its least expression. What a submarine torpedo did for the *Maine* in Havana harbour a torpedo dropped from a balloon or flying machine would do for any vessel afloat. This is the central fact of my contention.

"That the building of practical airships is still in its infancy, as a branch of the mechanic arts, may be conceded without discussion. I think I am fairly well informed as to every attempt in this direction. But enough has already been accomplished to warrant a great deal of nervousness on the part of the naval commander who is directed to take his ships on an unwelcome errand to a hostile port. He may be reasonably confident that the channel he must follow will be planted with mines of one kind or another, a chart of which is not likely to be furnished him. He will also in future have the disagreeable consciousness that from every point of vantage on shore an airship of one sort or another may be launched, each carrying the means of sending him and his crew to the bottom if it can be used as intended.

"I am not a naval architect, but I have studied the plans of warships a good deal, and can say, without fear of intelligent contradiction, that the strongest ship which it is possible to build in the present state of the art is vulnerable as to her decks. The reasons for this are very clear. Formidable projectiles have not been expected to strike decks. Small machine guns have been raised to cages built around the military masts of fighting ships at elevations of 30 or 40 feet; but a vessel thus equipped rarely gets near enough to its target to do more than rattle on its decks an annoying fire of small shot, which are deflected into space by the familiar phenomenon of the ricochet. If a shot from any gun practical for use above the deck level should penetrate a deck no great harm would be done; but the matter presents a very different aspect when the projectile is a bomb dropped 'plumb' on the deck from some point directly overhead, and so constructed as to explode by percussion or impact.

Am I right thus far, Commodore?"

The Commodore considered a moment and replied: "Yes, sir; you have very correctly and concisely stated certain familiar facts which are not open to dispute. In saying this, however, I beg not to be understood as accepting before I have heard them the conclusions to which they may have led you."

"All right, Commodore. I am not 'working a juggle to entrap your soul.' All I wanted was to be sure that we agree as to basic facts. If I am right as to these, discussion may lead somewhere; if I am wrong, or if you think me wrong, discussion would be useless. The action of high explosives in the open is well known. Owing to the fact that air compresses relatively slowly, it acts as an anvil when a large volume of highly expansive gas is suddenly liberated by chemical action. Hence the energy of such explosives is usually exerted downward, since the so-called solid earth is more easily disintegrated than the layer of atmospheric air above it is sufficiently compressed to accommodate elastic gases in large volume. A cartridge of dynamite or its equivalent, laid on the top of a rock ledge and exploded, will shatter the rock, often to considerable depths. This is a familiar phenomenon. Effected on the deck of a ship, such an explosion would collapse it, as one would collapse a pasteboard box by stepping upon it. Thus deformed, a ship would be as effectually rendered useless for any purpose as was the *Maine* when her keel came up through her middle deck. No part of her complex machinery of propulsion, turret revolution, gun moving, projectile lifting, steering or fighting would be likely to remain operative, and it is doubtful if any considerable proportion of the crew would be in a condition to take much interest in what thereafter might transpire, afloat or ashore. Again, am I right, Commodore?"

"I think so. If a projectile of the kind you have in mind should drop squarely, or in any other way, upon the deck of a war vessel as now built, and exploded there, I should expect very grave results to follow. Indeed, I do not know that you have exaggerated them in any respect."

Here the Doctor interrupted to say: "I see that Hiram Maxim, who is a pretty good authority on every phase of the subject, has committed himself to the opinion that the airship is practically useless for attack or defense at sea or ashore."

"Perhaps," continued the Engineer, "though I do not recall seeing him authoritatively quoted to that effect; and the opinion is so far at variance with what I should expect him to hold on this subject that you will pardon me if I am skeptical as to his ever having made any such statement. To be misunderstood and misquoted is the fate of every man whose opinions are sought by the newspapers."

"Could not the decks of vessels be so strengthened as to make them as invulnerable to sky bombs as to projectiles at sea level?" asked the Colonel.

"This question belongs rather to the Commodore than to me. However, as he seems disposed to hold his fire until he has the enemy at close range, I will venture to answer it according to my light. Possibly decks might be so designed as to minimize the danger of attack from above; but ships must float, right side up. It is quite conceivable they might be built so heavy as to weigh more than the water they would displace if submerged, or display an inconvenient tendency to 'turn turtle.' I am by no means convinced, however, that mere thickness of deck plating would impart invulnerability to deck explosions. If its effect was to submerge a ship she would be as effectually put out of commission, even if intact and undeformed, as if tied into a hard knot. But however this may be, there are probably no ships now afloat in which this dan-

ger is, or could be, provided for. If it be a danger, the navies of the sea would seem to be at a serious disadvantage in their relation to the navies of the air. As long as their respective efficiency is an open question, I can but think that such a plan as that attributed to the British Government of spending five hundred millions for new warships is a crime against posterity."

The Engineer rested. A murmur of approval was heard, showing that the Engineer's views had made an impression. After a moment the Professor took up the thread of the discussion:

"I have lately been brought so closely in touch with the progress of aerial navigation, in a consulting way, that I am beginning to think that a port well defended with craft of that class would be immune to molestation by anything that floated. Recent performances in this country and Europe have established the fact that the balloon and aeroplane, or the two in combination, if not practical for transportation in a serious way, are certainly capable of very efficient emergency service. A fair degree of dirigibility has been attained, and a flying machine which, in normal atmospheric conditions, cannot be steered as well as a ship in the water, while moving a great deal faster, is out of the competition. Their buoyancy is great enough to permit them to carry into the upper atmosphere sufficient high explosives to destroy pretty much anything upon which they might be dropped. Awnings or nets? Nonsense. To be effective they would need to be made of something comparable to interlaced steel rails.

"The whole subject is new and not many people know what progress has really been made in solving the problems of air navigation. What we read in the newspapers from day to day—and it is certainly copious in volume if not inerrant in accuracy—represents only a very little part of it. Within my own limited circle of clients and acquaintances I could probably name a hundred very ingenious mechanics and inventors, not yet heard of in this connection, who have been designing or building flying machines for the past four or five years, and some much longer. If my judgment is correct, a good many of these unborn devices are vastly superior to any that have been financed into publicity, and that is saying a good deal. The reason for this is that they are the work of people who have no sensational ends in view, are not dependent upon assistance from speculative investors to pursue their studies and experiments, and will make no announcements until themselves convinced that their results are the best possible in the present state of the art. In a time of national danger every one of the machines I have in mind could be amply financed, and I would undertake to find the capital for all who were ready to use it. But however many airships were built, twice as many brave men would risk taking them out to destroy a hostile fleet. The interesting fact of this development is that a hundred airships could be built and tested while the keel of one battleship was in the forge shop. There are in New York at the moment at least a dozen, and perhaps twenty, aeronauts and aviators who, for the offer of a small reward, would undertake to drop a dummy bomb on the roof of any building selected for the test. If the inducement was sufficient, at least a hundred contestants would be in the competition within sixty days, and, while not all would be successful, a large majority would. Half the number of those who could accomplish this at the first attempt would be enough to sink every ship of any fleet which might steam towards this port before it had passed the Narrows."

The Judge, who had listened closely, seemed to feel called upon at this point to hand down an opinion. Said he:

"I have found this discussion most

informative, and am glad to have been present. From what has thus far been said I, too, incline strongly to the conviction that the dirigible airship is a factor of no slight importance as affecting the availability of great naval armaments in the adjustment of future international disputes. Whether I mean the near or the remote future I am not quite sure. Every day seems to make more practical and more dangerous the agencies of ship destruction. Between submerged mines, floating and controlled torpedoes and bombs to be dropped on the decks from overhead, the warship would appear to have troubles of her own. What a naval commander would do if he saw the atmosphere crowded with airships of one sort or another, manœuvering to get him in range, and knowing that if a bomb from one of them dropped upon his deck and exploded there his trim ship would at once suggest the Panama hat of a college undergraduate in vacation season, is a problem in casuistry which appeals to the imagination. Commodore, you have said very little; and, if I am not mistaken, you are the only qualified expert on naval matters present. If you are restrained by considerations of official duty and responsibility from discussing the subject we will not press you; if not, we will be glad to hear from you."

The Commodore looked critically around the table. "Gentlemen," he began, "some facts have come to my knowledge officially which I assume would interest you very much; but these I could refer to only at the cost of a reprimand for a blazing indiscretion. The general subject I am free to discuss—provided, of course, I am not to be quoted, nor my name mentioned. Most of the gentlemen present I know; for the discretion of those I have not the pleasure of knowing I must ask my friends to assume responsibility. You will pardon this suggestion. I might warm up and say some things which my official superiors would hesitate to approve as wise at this time.

"My friend the Engineer has made a strong case and presented it forcefully—if I should say with the confidence of half knowledge, I trust he would not consider the phrase offensive. With his facts I have no quarrel; that his conclusions seem to me unwarranted is perhaps because I have studied the subject from a point of view which he does not appear to have taken. The same is true of my friend the Professor.

"I am willing to admit that airships are experiencing a very rapid development along what seem to be extremely practical lines. A degree of dirigibility has been attained which at one time, and that not long ago, would have been deemed impossible. To save time and avoid covering too much ground, suppose I note briefly the main points of the discussion up to this point.

"The plan of a loan of five hundred millions for the extension of the British Navy was formulated only a few days ago. I presume it will be carried out. The significant fact to me is that, during the last Channel manœuvers, a German airship hovered over the British fleet and was distinctly seen by every officer and sailor. The German Emperor is not without a sense of humour. In this instance his joke was hugely appreciated by the German newspapers, but I did not observe that the English papers gave it any greater prominence than its value as a news item warranted. The humour of it appears to have escaped them. Certainly the incident had no adverse influence in shaping public opinion on the subject of an increase of effective naval strength.

"I have no basis for a reasonable doubt that an efficient bomb, dropped from a high elevation upon the deck of a vessel, would do for her what the Engineer and the Professor have said. But I think the chances of this happening are so small as to be negligible. You probably recall that

many times during the past few years the extermination of navies has been confidently predicted as the result of apparently very satisfactory experiments with mines and torpedoes. But I do not recall that torpedoes have made any port invulnerable to invading navies. A few ships, mostly of the class used for scouting purposes, have been sunk; but it is doubtful if, in effectiveness, torpedoes and mines have repaid their cost. Back in the American Civil War, Farragut expressed the idea of the capable naval commander in his laconic and historic order: 'Damn the torpedoes! Go ahead!' The result justified his indifference to the danger he disregarded. Dewey, in Manila harbour, probably used very much the same form of words, but was not overheard; and his order to disregard the torpedoes which, it was understood, the Spanish authorities had planted broadcast in the bay, did not cost him a launch. When it was all over he sent around and gathered them up, as a fisherman would recover the takings of his eel pots. I do not mean to waste time over details of recent naval history, but the more you think of it the less ground you will find to recognize as well founded the conviction which obtained a few years ago that the mine and the torpedo had rendered the warship obsolete and useless.

"I do not know how many times it has seemed to those with imperfect knowledge of the facts that the designers of guns and projectiles had brought their weapons to a point of efficiency which permitted them to penetrate the vitals of any ship afloat, or which could be built and float. As the Engineer has remarked, ships could be made so heavy with protective armour that they would either go to the bottom as soon as launched or turn turtle. We began to plate ships with iron; then we found equal or greater resistance to penetration, with less weight, in steel; then we found that one kind of steel was stronger under the ballistic test than other kinds; now we can build ships which float very well and, above the waterline, are as nearly impenetrable as it is necessary or desirable to make them. The naval architect has kept in the race with the gunmaker and the inventor of projectiles, and at the present time he appears to be enough ahead to make him quite comfortable over the drawing board.

"It is extremely easy to make the same mistake concerning the value of the airship as a means of defense against the floating ship. Indeed, a great many are doing so. At this table two gentlemen of exceptional intelligence in such matters have expressed views as to the ease with which one of the former might destroy one or more of the latter by dropping bombs on her deck. No doubt they very correctly reflect the best thought of the public-spirited citizen without official responsibility. With the position of my friend, the learned divine on my right, I cannot take issue. I, too, desire world peace; but if I do not see it as likely to be attained in the near future it is because I happen to know what small and insignificant incidents are capable of magnification into pretexts for war when public passion is inflamed and commercial interests demand protection from the sword. But with the position of the learned Engineer and the no less learned Professor I am prepared to take issue as squarely as the courtesies of dinner-table discussion will permit.

"Much that has been said this evening suggests the thought that perhaps the Navy Department does not know what is going on in the field of flying-machine exploitation. I doubt if any department of the government is nearly as well informed on every step of this progress as it is our duty to be. Not only are we fully advised as to everything done or doing, but the moment an inventor takes his ideas to the Patent Office he takes the Government of the United States into his

confidence; and, having done this, he may expect that the government, as represented by its authorized agents, will know all he is pleased to declare."

The Engineer and the Professor exchanged glances which to each meant a good deal. The latter interrupted:

"Excuse me, Commodore, but do you mean to say that when an inventor files his application for a patent, if it relates to an airship of any kind, his confidential communications are turned over to the Navy Department for examination? That is new to me."

"No," replied the Commodore, "that is neither what I said nor meant. Perhaps what I did say would not have been said at all if I had dined less generously and taken fewer glasses of our host's very excellent wine. However, I have said nothing which is not clearly set forth in the law and in the rules of practice of the Patent Office. A patent is not a right; it is a privilege. It is granted or refused in the discretion of the government. Now, the government is not merely a bureau of the Interior Department, but a very complex machine of many parts. When appealed to for a valuable privilege, such as a monopoly of the right to make and use a machine which may be of great value in the national defense or as an element of its strength, it would seem quite natural that the Departments immediately interested should be consulted through qualified and discreet representatives. Let me also remind you that Section 63 of the Patent Office Rules of Practice provides that 'applications wherein the inventions are deemed of peculiar importance to some branch of the public service, and when for that reason the head of some Department requests immediate action and the Commissioner so orders (shall have precedence); but in such case it shall be the duty of such head of a Department to be represented before the Commissioner in order to prevent the improper issue of a patent.' I will not interpret this; probably you do not need that I should. As inventors, you should know more about these things than I do.

"Having said this much, however, it will probably not be deemed an indiscretion to generalize a little. Every Department of the government is represented in the Patent Office, and receives therefrom the information of especial interest to it. In no other way could the government protect itself against demands which would bankrupt it, or know the 'state of the art' in what it is itself doing. I know of no instance in which this right of the Departments has been abused or used to the disadvantage of an inventor. The inference from all this is that the Navy Department knows not only what has been made public, but also whatever of real interest inventors are seeking to protect. It is part of my duty to collate and use this information properly, and it will, perhaps, give weight to my general dissent from the thesis of the Engineer if I say that nothing described in the patents or patent applications of this or any other country seems to warrant the belief that the floating ship is as yet seriously menaced by the flying ship.

"Let us look at the matter practically. Airships can fly, some of them can remain in the air for several hours, and a few can cover long distances and return with, perhaps, as much safety as a ship can navigate strange waters in bad weather. A few of them have enough buoyancy to carry very formidable bombs, which, if dropped upon the decks of ships, would probably render them useless for any purpose. Within another year, or possibly six months, still stronger, more accurately controllable and more buoyant airships may be invented and built. But do you suppose that this danger has grown up and taken shape without attracting in the Navy Department

all the attention it merits? To think so would be to rate us among the hopeless incompetents, who should be sent to schools for feeble-minded children.

"In the first place, no tests yet made would seem to show that an airship of any type could drop a bomb on a surface relatively so small as a ship's deck unless by mere chance. The proportion of misses to hits would be much greater than in the case of gunfire, and there it is so large as to surprise the layman. I doubt if, of bombs dropped from rapidly-moving airships, one in a thousand would come within a hundred yards of the vessel for which it was intended. There are several reasons for this. I have no doubt that dummy bombs might easily be dropped upon the roof of any building in New York selected for a target; but the airships which would drop them would fly low, and thus render their task comparatively easy. The airship which, in pursuit of a floating ship, should fly low, would never get above her in daylight, and at night she could not find her. The uncertainty of 'aim' in anything dropped from a height, the difficulty of making due allowance for movement in both crafts, deflection by air currents, and the fact that a ship is a very small spot on the surface of the ocean, are elements of difficulty in an attack of this character which must not be overlooked. If a ship would remain obligingly stationary and permit the balloon or aeroplane to hover over her like a blooming dove of peace about to alight with pink-tipped feet on her turret, she might accomplish it. But naval commanders have a prejudice against taking soundings by themselves going to the bottom. How far do you think some of the small-bore, rapid-fire rifle guns available for distribution or already in use will carry?" (This was addressed to the Engineer.)

"Possibly a mile or so on a relatively horizontal plane of fire."

"Yes, and two and a half to three miles more. Tests made within a month show that shots of size and weight sufficient to wreck any kind of an airship can be discharged very rapidly to a vertical elevation of something over two miles, and at angles from the perpendicular of nearly or quite four miles. This means that as soon as a hostile airship came within four miles of the floating ship it was after the latter would begin hurling projectiles at her. It would require good marksmanship to hit her at that distance, but as she drew nearer the chances of crippling her would increase. It may interest you to know that there is already in use a very simple form of telescopic sight so adjusted that a gun to which it is attached may sweep the entire arc from horizon to horizon, and with aim as accurate as if trained on a floating object. No, excuse me, I do not care to go into details too specifically. At four miles, or even three miles, such a target would be comparatively safe unless the gunner made what in billiards is called a 'scratch'; but long before the airship got near enough to drop a bomb within a thousand feet of the deck of a vessel I was commanding I would undertake to break its wings, or smash its motor, or even more completely to wreck it. This, of course, presupposes daylight. At night my ship would not be likely to be where an aeroplane or balloon could find her, or if her general position was known, to get it in range for a projectile dropped with the relatively low velocity due to gravity."

"One moment, Commodore," said the Engineer. "I do not doubt that you have very admirable and plausible guns for airship destroying, but I very much doubt if they will make good in use. The problem looks easy enough, but it is not easy at all. Perhaps you will recall that, about four years ago, when the military balloon was attracting a good deal of attention and exciting a good deal of

speculation in Germany, the army people were very sure that no balloon could get near enough to a German post to do any harm. An order was placed with Krupp for a gun which should keep the circumambient atmosphere free from that kind of intruders. Well, the gun was built. It was a small-bore rifle of great range and very high projectile speed, and was as perfect a piece of mechanism as was ever turned out at Essen. It was so mounted as to sweep the sky at every point, had range-finders, telescopic sights, and all the refinements of scientific gun-building. When it was finished a series of tests was made with it, with the net result that, after many weeks' trial under all sorts of conditions, obviously difficult and seemingly easy, not one balloon target was touched. The experiment, most disappointing to the Krupp people, to the army sharps and to the government, was abandoned. The Germans know that what you so confidently promise cannot be done."

The Commodore looked uneasy, but turned the discussion by a remark to the effect that the road to success was often found through failure, and that one might learn a great deal from the scrapheap of four years ago. But the Engineer was not disposed to accept commonplaces in lieu of facts. He continued:

"I do not want to press you with questions which may be officially embarrassing, my dear Commodore; but I should like to present for your consideration a hypothetical question, which you may not care to answer, but which will bear consideration. You think it improbable that an airship could find you at night in hostile waters. If she carried no lights is it probable you could find her?"

"No, I think not."

"Do you remember at what depth the *Challenger* took her famous deep-sea soundings?"

"No, not accurately. It is a long time since I had occasion to refresh my memory on that point."

"Some of her soundings were made at the depth of eleven thousand fathoms, were they not?"

"That is my recollection."

"Good! Now the hypothetical question I wanted to ask is this: Suppose an airship drawing near a warship, but still at a considerable distance from her, and, it may be, uncertain of her exact position, should pay out a thousand or more feet of piano wire, at the end of which was a bomb so arranged as to be exploded by an electric spark. Whether the bomb swung clear of the water or dragged in it would make no difference. Now suppose an airship with this kind of pendulous tail should cruise around overhead until the wire became entangled in some part of the superstructure of your ship. It would have found her without doubt. Now suppose the jerk of resistance should establish the connection and send a spark down the wire from a battery in the airship, and the bomb in contact with the floating ship was exploded. What would happen?"

During the formulation of this question the Commodore showed every evidence of tense interest. He looked almost startled, but as well as possible concealed any evidence of excitement. He fumbled his napkin, made a pretence of relighting a cigar already burning nicely, and looked significantly at his host, the Professor. After a moment's pause the Professor said:

"I think, gentlemen, it might be wise to adjourn to the library. Some of our friends may find the change agreeable. As to the hypothetical question which has been dropped on the Commodore, like a bomb on his quarterdeck, it is scarcely fair to ask him to answer it offhand. There may be reasons why he would prefer to discuss it in Washington before he does in New York. It has been a most instructive exchange of views on a most important subject. Now I should like to show you something possessing interest of a very different

sort—a tube of liquefied helium, the first seen in this country." The discussion was not resumed.

Later, when the party was breaking up, the Commodore found himself alone for a moment with the Professor, to whom he whispered:

"Our friend the Engineer knows a little more than I wish he did. There was nothing in his recent patent applications about swinging bombs depending from piano wires."

"No," replied the Professor, "there are some things too dangerous for proclamation in that way."

"You are right; no less true is it that there are some suggestions too dangerous to be discussed in a mixed company of quick-witted and appreciative people, who have not learned the great truth that if one knows anything worth telling the best thing he can do with it is to keep it to himself. Good-night."

PROTECTION AGAINST FOG DANGERS AT SEA

By J. Erskine Murray, D. Sc.

THE transmission of position and danger signals at sea is a question of such immense importance to the commerce of the world that it is remarkable that, up till quite recent years, the mariner has had to depend on such uncertain indicators as the sound of a siren or the rays from a lighthouse, neither of which is capable of conveying its message to him in thick and stormy weather.

In recent years this reproach has been to some extent removed by the invention of electric wireless telegraphy; but though it is now possible to locate with very considerable accuracy the direction from which a wireless signal has come, the apparatus necessary for doing so is, as yet, rather cumbersome for use on board ship. No doubt in future this difficulty will be got over, but at present electrical methods cannot offer an entirely satisfactory substitute for the lighthouse or siren. The complete electrical solution of the problem is hardly as simple as might appear at first sight; for, under favourable conditions, the older methods give not only an indication of the direction from which the signals are coming, but also show, roughly, the distance of their point of origin from the ship on which they are observed. Thus, in clear weather, the apparent brightness of a light and the rate of its apparent angular motion as the vessel passes it, give, to one accustomed to observing them under all conditions, a rough but useful idea of its true position. This is rather more than can be said, as yet, of even the most refined electrical methods suitable for use on board ship. It should be noticed, however, that the directive systems of wireless telegraphy developed by Marconi, Braun, De Forest and Tosi make it possible for a land station to obtain the bearings of a vessel and to transmit the information to the ship, even though the latter is fitted with only ordinary non-directive apparatus.

The first suggestion of true submarine signalling was made a number of years ago by Mr. Charles Stevenson, engineer to the Northern Lighthouse Commissioners, who proposed the laying of a cable, in which an alternating current would be maintained, along the hundred-fathom line round the coasts, to enable vessels fitted with proper apparatus to recognize their arrival at this important landmark, if so we may call it. The proposal has not, however, been carried out, owing no doubt to the high capital and running costs and to the fact that the electrical apparatus on board each ship would be useful only for the one observation on the voyage and not for general purposes of communication.

Ordinary modern methods of wireless telegraphy, depending on electrical currents, or waves, of high frequency, are quite useless for submarine signalling, as these currents do not penetrate through more than a very few fathoms of sea-water. Since sea-water is almost as opaque to light waves, there remains only the alternative of establishing communication by means of sound waves, which, after all, are merely compressions and rarefactions of the water itself. These are caused by the to-and-fro motion of the sounding body, and travel out from it in concentric

spheres, the radii of which continually increase at the rate known as the velocity of sound in water.

Luckily for the mariner, the difficulties incidental to communication by sound through the atmosphere are almost entirely absent where the sea is concerned. There are no hurricanes in the sea, no currents which run more than a very few miles an hour, none of the turbulent vortex motion invariably present in wind storms; and, in addition, sound waves have a much higher velocity, and sound shadows cast by solid bodies in their path are far more sharply defined in water than in air. Thus a sound travels a far greater distance in water than in air; it is not affected by storms, for the greatest of surface waves do not disturb the serenity of the ocean to a depth of more than a few fathoms, and its direction is very easy to locate. In addition to this, it is clear that in shallow water the sound is practically confined to the layer of water between earth and air—for there is reflection at both surfaces—and hence varies in intensity much less rapidly than as the inverse square of the distance.

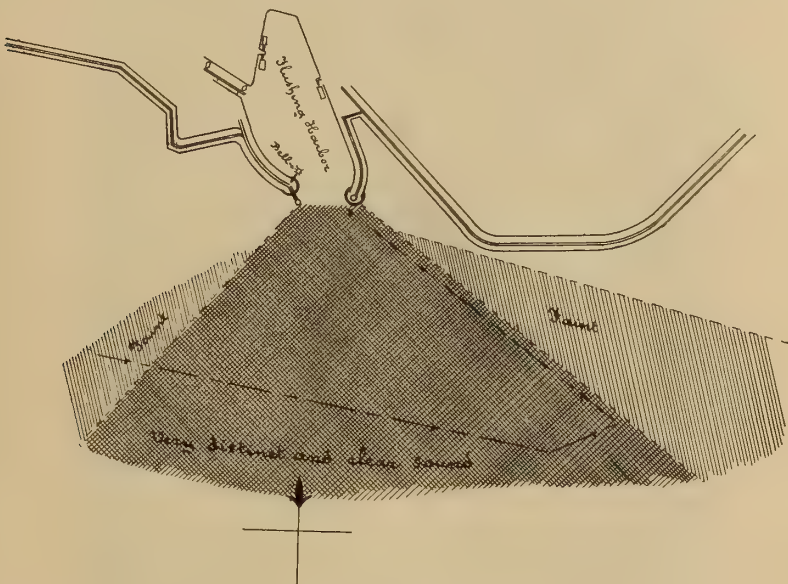
It is these advantages over other methods of marine signalling which have rendered the adoption of submarine bells and signalling apparatus so rapid and so general. There are already more than 224 sea-going vessels and yachts, besides 80 lightships, equipped with submarine signalling apparatus. In addition to these a large number of naval vessels, both of ordinary and submarine types, use this system of communication.

Many years ago, when the velocity of sound in water was first measured in the Lake of Geneva, it was found that the sound of a bell rung under water was easily audible four or five miles off in an ear-trumpet the outer end of which was submerged. Later experiments showed that a sound made under water can be heard even through the thick planking or plates of a ship's side, though the source of sound may be a mile or more away. The transmissibility of sound was thus proved, but its application to marine signalling was not immediate, for in the course of experiments many difficulties cropped up which had to be overcome. The greatest of these was the avoidance of interference by other noises, the most of which had their origin in the vessel itself or were caused by the rush of water past the receiver. Many inventors studied the subject without conspicuous success previous to the publication of Elisha Grey's method of receiving sounds by means of a submerged microphone connected to a telephone at which the observer could listen. The advantages of this method were, however, soon apparent, and it rendered possible the researches of Mundy and Millet, which resulted in the development of a practical system of submarine communication. Mr. Millet now works in conjunction with the Submarine Signal Company of Boston, the organization which has installed the apparatus in the vessels and lightships above referred to.

It is the ease with which it is possible to determine the direction in which sound is traveling that makes submarine signalling so valuable. This is mainly due to the great density of water, which has over seven hundred times the density of air. The momentum of a sound wave in water is thus very great; it does not bend itself around corners and spread into spaces behind obstacles, but travels forward, leaving sharply defined patches of silence, which may be compared with the dark shadows cast by solid objects on a clear moonlight night. This effect is well shown in the illustration, which is drawn from actual observations. The sound shadows cast by the piers, shown by the lightly shaded and white parts of the plan, are wonderfully sharp, and the navigating officer, listening to the bell as the vessel moves across the mouth of the harbour, is able to recognize at once the sudden weakening of the sound, which indicates

that he has reached the point at which he must turn his vessel directly towards the bell in order to enter the harbour in safety.

It is this property of sound waves in water that is chiefly effective in rendering it possible to direct the vessel towards the bell. On either side of the bow, well below the water-line, are placed microphonic receivers against the inside of the outer plating, or skin, of the ship, each



SKETCH OF FLUSHING ROAD

Showing the area in which the submarine bell is audible and the course of a vessel entering. (From a tracing kindly lent by the Iceland S. S. Co.)

of which is connected to a telephone in the wheel-house. The navigating officer compares the strength of the sound of the bell as heard in the two microphones and alters the course until they appear to be equal. He then knows that the bell is right ahead.

It has been found by trial that the probable error in the bearing found by this means amounts to only a degree or so; indeed, the results obtained by the Cunard liners *Ivernia* and *Lucania* in 1906 indicate a possible error of only a small fraction of a degree, although the distance at which the bell was heard was as much as eight or ten miles.

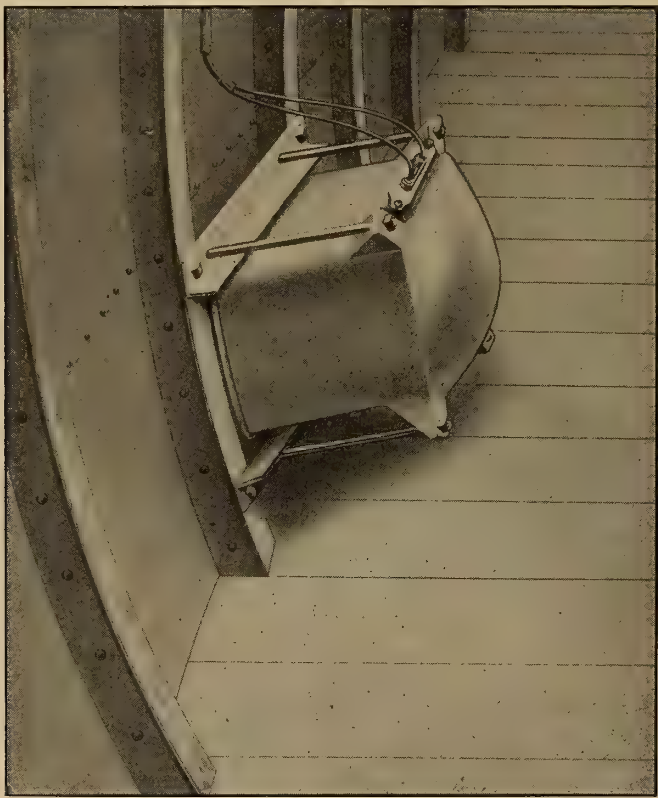
In the earlier experiments microphones were suspended in the water alongside the vessel. It was found, however, that the noise caused by the motion of the apparatus through the water masked the sound of the distant bell. The microphone was next placed in a small fishlike float, constructed so as to cause as little disturbance in the water as possible. This gave better results, but still did not completely satisfy the inventors. Taking the bull boldly by the horns, they next placed the microphones inside the hull, in tanks completely full of water fixed against the outer plating, or skin, of the ship, and it is this method which is now in use.

The receiving tanks are insulated from the vessel's sides, as regards transmission of sound, by interposed washers of rubber or similar material. Thus the receivers are not affected by vibrations traveling along

the plating, but only by those which strike it on the outside, causing it to vibrate in and out, thus increasing and diminishing alternately the pressure in the tank and so affecting the microphone.

Under these conditions the sound of a bell sixteen miles off has been heard on board ship—a result which demonstrates beyond question the practical utility of the system.

The bell with which this wonderful result has been obtained is not of great size, nor does it differ greatly from bells for other purposes. It is, however, always tolled, not rung—i. e., the tongue only is moved, and the mechanism is such that the strokes are exactly of equal strength. In small bells, suitable for use at pierheads, the ringing is done by means of a hand line, while in larger installations, where the ringing is continuous, compressed air or an electromagnetic engine is used. For outlying banks a bell buoy may be used, the action of the waves being sufficient to drive the ringing mechanism. A bell of this description was for many months in operation at the Nab (near Portsmouth), and rang continuously, even when the rise and fall of the waves was no more than 2 inches. This bell was invariably heard at five miles and frequently at much greater distances.

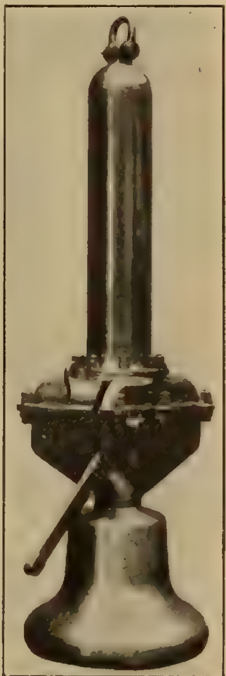


TRANSMITTER-CASE IN HOLD OF SHIP

And connected electrically with receiving telephones in pilot-house

The pierhead bell which is in use in Flushing harbour is shown in the illustration. The lever which actuates the driving mechanism, with the ring-

ing line attached, is clearly shown. The bell is suspended from a davit on the quay by a rope through an eyebolt at its top and hangs submerged a few feet below water. Inside the cylindrical part of the casing is a spiral spring, which is strained by the motion of a ratchet-wheel when the lever is pulled by the line. When the tension reaches a certain amount the spring is suddenly released and, pulling the clapper, gives one stroke to the bell. The use of the spring gives a regular and certain action not attainable by direct pulling by hand, since the stroke of the clapper is due to a certain definite compression of the spring, which is always the same, and not to the strength of the pull given to the line. This regularity of action, and consequent uniformity in the sounds produced, is, of course, of much importance, since the mariner can thus make reliable comparisons between the sounds heard in the telephone at different moments. In larger installations, such as lightships, where the bell rings a code signal day and night in foggy weather, it is obvious that manual power would not be sufficient. As a matter of fact, two different kinds of motive power are used, according to the distance of the bell from the controlling station. On light vessels, where the bell is merely suspended over the ship's side from a davit, the most convenient agent is compressed air, supplied by a small compressor driven by an oil engine or by steam from the boiler if the vessel has one. The supply of air to the striking mechanism of the bell is controlled by the "code ringer," which consists of a slowly revolving disc with projecting teeth corresponding to the strokes which the bell is required to ring. As the disc revolves, each tooth, in turn, opens the air valve for a short time, admitting air under pressure to the supply pipe of the bell, causing the clapper to give one stroke. Since the revolution of the disc is uniform, the interval between successive strokes is proportional to the distance between successive teeth. Thus Lightvessel No. 54, in Boston Bay, rings its number as five strokes, followed by a silent interval of three seconds; then four strokes, followed by five seconds' silence. The code ringer disc is visible above the air compressor, from which it is driven by means of a belt and slow-motion gearing.



SUBMARINE BELL SUITABLE FOR USE AT PIERHEADS

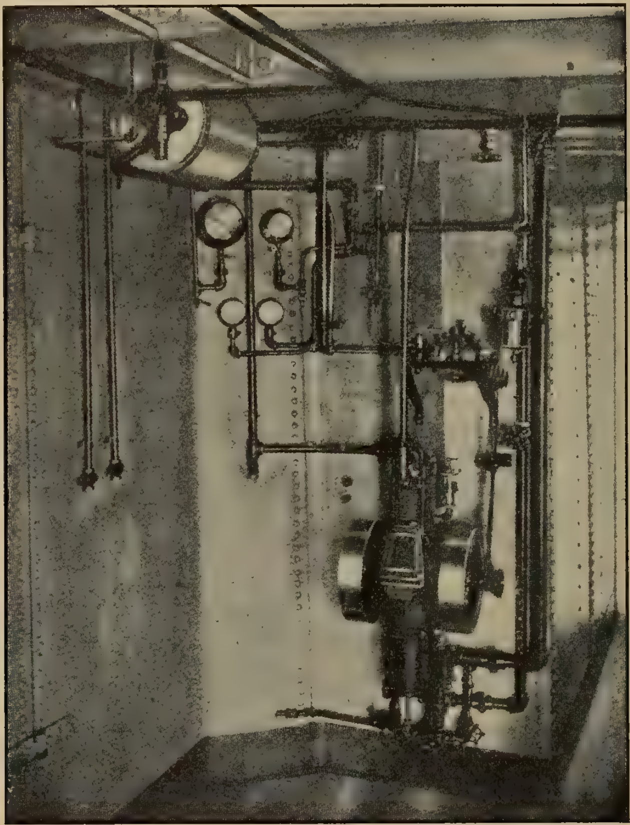
For places where the bell is situated at a greater distance from the controlling station electrical power is used for transmission. Thus the Chebucto Head bell, which constitutes a turning-point for traffic entering the harbour of Halifax, on the coast of Nova Scotia, stands on an iron tripod 70 feet below water and two miles from shore. It is rung by means of powerful electromagnets actuated by an electric current from a small power house on shore. The current is conveyed to the bell through a cable, of which a telephone

circuit also forms part, so that the attendant on shore is able to hear that the signals are being correctly given. The bell was started on March 30, 1907, and had rung over a million strokes by the middle of May, its rate being twenty-two strokes per minute. The Canadian Government has equipped a number of other points on its coast in a similar way.

These and many other bell stations are shown on the accompanying sketch chart of the American and Canadian coasts.

The receiving instruments used on board ship consist of the port and starboard tanks, already described, each containing a pair of sensitive, watertight microphones connected by insulated wires to a battery and telephone in the wheel-house. Only one microphone in each tank is normally used, the second being occasionally switched on as a check on the indications of the other.

An ordinary microphone is simply a small box containing grains of carbon packed somewhat loosely. One side of the box is a fixed plate of metal or carbon and the other a thin, flexible disc, which moves in and out in accordance with the pressure of the sound waves striking on it; as it does so it increases or decreases the electrical conductivity of the loose mass of carbon granules, thus varying the strength of the current passing through the microphone from



AIR COMPRESSOR AND CODE RINGER INSTALLED IN ENGINE ROOM TO OPERATE THE SUBMERGED BELL SUSPENDED FROM DAVIT OF LIGHTSHIP

SUBMARINE BELLS ON THE COASTS OF THE UNITED STATES AND CANADA

UNITED STATES

No.	Lightship	Gov. No.
1.	Cape Elizabeth, Me......	74
2.	Boston, Mass...........	54
3.	Pollock Rip Shoals, Mass.	73
4.	Nantucket Shoal, Mass..	66
5.	Hen and Chickens, Mass.	86
6.	Vineyard Sound, Mass..	7
7.	Brenton Reef, R. I......	39
8.	Cornfield Point, Conn...	48
9.	Fire Island, N. Y.......	68
10.	Sandy Hook, N. Y......	22
11.	Northeast End, N. J....	44
12.	Five-Fathom Bank, N. J.	5
13.	Overfalls, Del...........	69
14.	Fenwick Island Shoal, Md.	3
15.	Winter Quarter Shoal, Va.	45
16.	Cape Charles, Va.......	49
17.	Tail of the Horseshoe, Va.	46
18.	Diamond Shoal, N. C...	5
19.	Frying Pan Shoals, N. C.	1
20.	Martins Industry, S. C..	53
21.	South Pass, La..........	43
22.	Heald Bank, Tex.......	81
23.	Brunswick Bar	84
24.	Pollock Rip, Mass.......	5
25.	Cape Lookout Shoal, N.C.	80
26.	Ambrose Channel, N. Y..	87
27.	Great Round Shoal......	

Shore Stations

A, Point Allerton........

CANADA

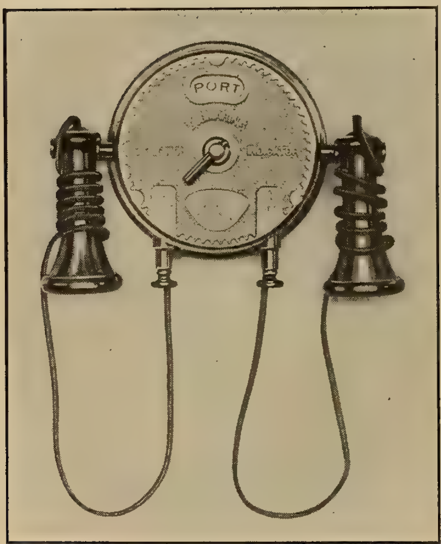
No.	Lightship	Code
1.	Prince Shoal	7
2.	Red Island	3
3.	White Island	5
4.	Anticosti	15
5.	Lurcher Shoal	14

Shore Stations

A,	Chebucto Head..........	4
B,	Louisberg	
C,	Yarmouth	
D,	Negro Head (St. John's), N. B.	

the battery to the telephone receiver. The result is that the disc in the telephone is made to move, by the varying action of the current, in exact accordance with the variations of pressure on the microphone. Thus the sound vibration, striking on the microphone, is exactly reproduced in the telephone.

A switch at the telephone enables the navigator to connect alternately to the port or starboard microphone and compare the strength of sound from the bell on either side of the ship. The appearance of the apparatus is shown in the illustration. In using it the navigator alters the course of the vessel until the port and starboard sounds are equal, indicating that the bell is right ahead. He can then either steer directly for the bell or lay his course by the bearing thus obtained.



DIRECTION-INDICATOR AND RECEIVING TELEPHONE

The bell thus provides a way of obtaining the bearing of a fixed point with sufficient accuracy for practical navigation, which is equally reliable in all weathers whether by day or night. That this is actually the case has been amply proved by the experience of the masters of such vessels as the Cunard liners *Lucania* and *Ivernia* and many others. Captain Watt, of the *Lucania,* reported as follows on April 7, 1906: "We had hazy weather, with showers of misty rain, off the Nantucket Shoals, and we would have failed to locate the lightvessel but for the aid of the submarine signal bell. We heard it eight and one-half miles distant while steaming full speed at 22 knots. We made the lightvessel one point on the starboard bow and passed it one-third of a mile off, which enabled us to obtain a good departure. The sound of the bell was musical and distinctly audible, and could not be mistaken for any other sound. To my mind, this is a very satisfactory experience, as it brings home to one the practicability of the system." The exactness with which the course, set by the bell when eight miles distant, brought the vessel to the desired point, is a proof of the accuracy with which the direction of a sound in water can now be determined.

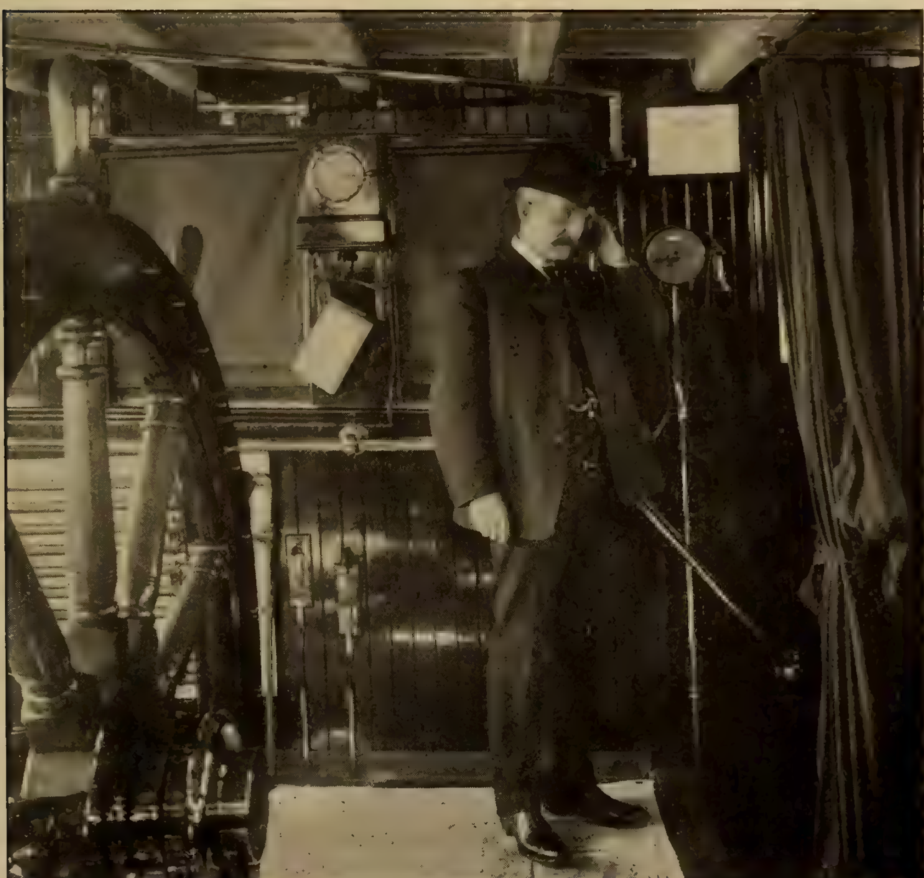
A report by Captain Turner, of the *Ivernia,* gives an even more convincing proof of the utility of submarine signals. It reads: "I wish to report that, on the afternoon of March 15, 1906, in a blinding snowstorm, when ten nautical miles distant from Lightship No. 54, and going slow and stopping, we heard the submarine bell distinctly on the port bow, and forty-five minutes before the fog-whistle. We made the lightship right ahead by altering the course one-half point to port. This is the best result I have had, and I consider it a splendid adjunct to aids in navigation in thick weather, of course making use of the lead also."

A more recent report, by the master of the North-German Lloyd steamer *Chemnitz,* may also be alluded to. It is dated March 19, 1908, and gives an interesting account of the use of the bells recently placed at important points in the North Sea and Channel. The Nord-

hinder Lightship bell was heard at a distance of ten miles, the Sandettie and East Goodwin bells at from ten to fifteen miles, and although the latter lightship was passed at only two miles distant, its ordinary fog signal was quite inaudible on account of a fresh southerly breeze. The submarine bell, therefore, was the only evidence of its existence and of the vessel's proximity to a dangerous shoal.

From the sketch chart showing the location of submarine bells on the coasts of Europe it will be seen that, as yet, these are very few in number as compared with those on the American coast. But a good beginning has been made, particularly on the eastern coasts of the North Sea and in the Mersey. Bells are also being placed at Ushant, Cape Roca, in Portugal, and Tarifa, on the Straits of Gibraltar, which should be of great service to vessels on the eastern and African routes, and may avert in future such terrible disasters as occurred to the *Drummond Castle*, *Serpent* and *Roumania*.

The remarks of the chief engineer of the Canadian Department of Marine and Fisheries, quoted by a member of the recent Royal Commission on Lighthouse Administration, are interesting reading, and show how much has yet to be done on the



RECEIVING SIGNALS IN THE PILOT HOUSE

The direction indicator enables the captain to ascertain the direction from which the signals come

SUBMARINE BELLS ON THE COASTS OF EUROPE

No.	Lightship	Code
1.	Kiel. Gabelsflach	54
2.	Weser	5
3.	Elbe	4
4.	Aussen Jade	222
5.	Sandettie	3-1
6.	North West	3
7.	Terschilling	3
8.	Haaks	
9.	Maas (1908)	
10.	Schouwen	
11.	Norderney Gat	3
12.	Fehmarn Belt	9
13.	Tender at Boulogne	3
14.	Tender at Cherbourg	9
15.	Danish State R.R.	
16.	Borkum Riff	9
17.	Mersey Bar	6
18.	Royal Sovereign	3
19.	Tongue	4
20.	East Goodwin	6
21.	Outer Dowsing	4
22.	Havre Bell Buoy. On order.	
23.	Ushant.	
24.	Cape Roca.	
25.	Tarifa. Under consideration.	
26.	Cap Ortegal.	
27.	Cap Villano.	
28.	Vigo (2).	
29.	Leixoes.	
30.	Burlings.	

English coasts to bring our lightships up to date. He says: "A modern lightship, such as those lately moored off Anticosti and off Lurcher Shoal, in the Bay of Fundy, is a perfect battery of ingenious mechanisms. From the electric lights at her mastheads, automatically occulted by clockwork, making and breaking the current produced by a dynamo in the engine room, to her moorings connected with powerful automatic buffers and steam windlasses to relieve the strain on her bows, she is full of machinery. She is self-propelling, provided with a powerful fog alarm, a submarine bell and a Marconi telegraph instrument. For the design of these vessels we are indebted to the United States Lighthouse Board, whose plans were adopted under the conviction that its long experience with lightships in the open Atlantic was too valuable to be ignored." The British Commissioner remarks (January, 1908) that "we do not appear to have any modern lightship of this advanced type on the coasts of the United Kingdom."

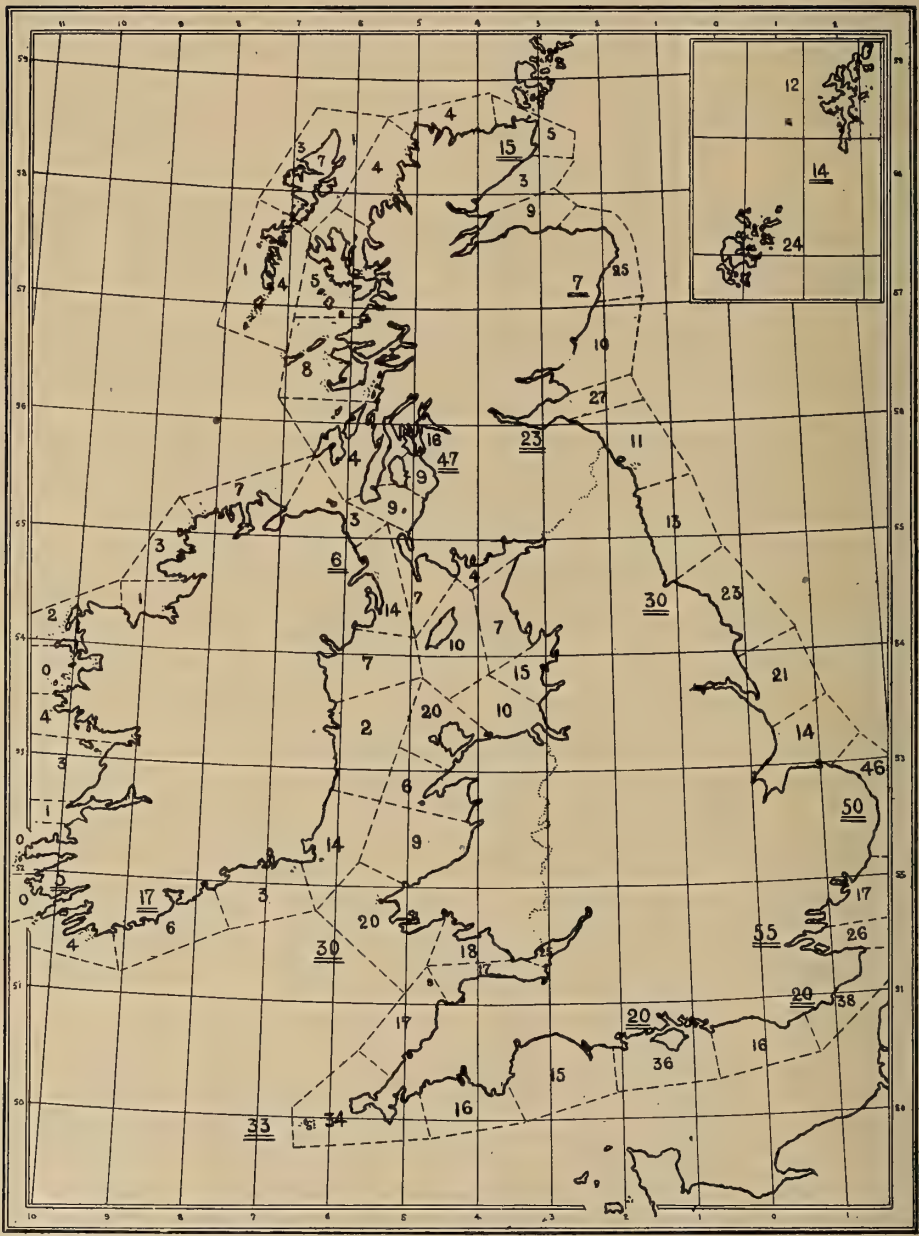
For the purpose of assisting in the determination of the localities in which fog signals of a really efficient and reliable type are most urgently required, the writer has gone, during the past ten or twelve years, through a large amount of statistical matter on Wrecks and Casualties to Shipping, published by the Board of Trade. He has also deduced from the figures given by Dr. R. H. Scott, in his paper on "Fogs," published in the Royal Meteorological Society's Journal for 1893, the average number of foggy days per annum at several important places along the coasts of the United Kingdom. A proper combination of the results thus obtained will give an indication of the localities in which fog is, at any rate to a large degree, responsible for the danger to shipping.

Before going into the actual figures it will be advantageous to define as clearly as possible the quantities which have to be dealt with. First, there is what we may call the intrinsic danger of a locality. Taking the vessel, and not its tonnage, as a unit, this quantity may be stated as

$$\frac{\text{Total number of casualties per annum in district}}{\text{Total number of vessels passing through district}}$$

This quantity, though of importance to the shipmaster or shipowner in deciding on the route to be taken by a vessel so as to avoid danger, is not the criterion which indicates the necessity for better danger signals. It shows clearly the most dangerous parts of the coast to any vessel which may go there, but it does not indicate the actual loss of life and material occurring annually at these points. From this latter point of view we have other quantities to consider, firstly the number of lives lost per annum, and secondly the total tonnage involved in casualties. The two do not appear to be proportional, since the number of lives lost in casualties to, say, 100 fishing boats, aggregating 1,000 tons, is usually greater than that caused by casualties to two vessels of 500 tons each. The actual danger to life is, therefore, not directly proportional to the commercial loss. This last is represented by the total tonnage involved in casualties in any given district during the year. For the British Islands it amounts to about half a million tons per annum. The total loss of life last year was 269 persons. Both are losses of national capital which it would be well to avoid as far as possible.

The accompanying chart shows the number of cases of total losses or serious casualties which occurred during the year ending June 30, 1906, in each of the marked areas. It also shows the average number of foggy days per annum as calculated from Dr. Scott's figures. Besides these, there were about twice as many minor casualties, in all 3,685. Examination and summation over ten or twelve years of the losses in various districts show that, at any rate where the traffic is great, the figures



WRECK AND FOG CHART OF THE BRITISH ISLES

The small numbers indicate the number of total losses and serious casualties for the year 1905-06 within the areas bounded by the dotted lines. The underlined numbers show the average number of foggy days per annum.

of the chart represent very fairly the average annual totals. In considering them from the mercantile point of view it must, however, be borne in mind that the greatest aggregate delay to shipping does not necessarily occur at the points where most ships are lost, but rather at points where the danger is so obvious that a shipmaster feels fully justified in not attempting a passage during fog. It is thus at such points as the entrances to the Solent and Mersey that the greatest aggregate waste of time occurs, though not the greatest number of wrecks; and it is the very width of the Bristol Channel, combined with the prevalence of summer fogs, which renders the Scillys and Lundy Island so dangerous.

The underlined figures shown on the chart are only supposed to include true fogs and not mist or haze. As, however, the distinctions between these terms are by no means well defined, it may be that the observers at the stations from which the reports were received have gone upon somewhat different standards. It is certain, however, that every entry represents a state of the atmosphere highly dangerous to navigation, and that many "mists" are omitted which might well have been included as fogs from the mariner's point of view.

Taking into consideration, then, the above data as to fogs and casualties, it appears that the order of urgency in the improvement of marine fog signalling in various localities comes out somewhat as follows: The coast of Norfolk and Suffolk with its outlying sand banks, the mouth of the Thames, the promontories of Kent and Sussex, including the Forelands, Dungeness and Beachy Heal, the Solent and Isle of Wight, the Scillys and Western Cornwall, South Wales, the Firth of Forth, the Little Cumbrae, the Yorkshire coast, and probably Anglesey. In these stations the coincidence of a large number of serious casualties with a large number of fogs per annum indicates the nature of the danger. In other dangerous localities the small number of fogs recorded shows the danger to be mainly due to other causes.

Among places at which wrecks are not so frequent but which are on the track of great passenger lines may be mentioned Mizen Head, the Fastnet Rock, the Tuskar Rock, the Isle of Man and Inishtrahull.

The increase in the reliability and number of danger signals round the British coasts cannot fail to reduce that large annual number of casualties which are set down in the reports as "purely accidental" or "inevitable." Under past conditions they, no doubt, were properly so classed; but, after all, these terms merely imply that the navigating officer has done the best that could be done under the circumstances—i. e., that he had, and could have, no knowledge of impending danger, and could, therefore, take no steps to avoid it. It is the business of those in charge of our coast signals to alter these circumstances for the better, and to supply mariners with submarine bells, wireless telegraphy or other means that, unlike lights and fog-horns, will be reliable in all weathers, and so give him that knowledge of the vessel's position which is essential to its safe navigation.

THE NATIONALIZATION OF RAILWAYS

THE PRACTICAL WORKINGS OF STATE OWNERSHIP IN VARIOUS COUNTRIES

By C. S. Vesey Brown, M. Inst. C. E.

THE facilities with which reliable information on various public matters can be obtained is demonstrated by a recent document issued under the authority of the English Board of Trade on the subject which forms the title to this article. It is not the intention to ventilate the arguments for or against State ownership of railways, as the subject bristles with debatable points from whichever side it is faced, but, in view of the oft-repeated request by certain political parties in Great Britain and elsewhere for the complete nationalization of the railway system, it is thought that a resumé of the results, etc., in those countries where railways are under the direct control of the State will be of interest.

Forty-three of the separately governed countries of the world have decided in favour of State ownership. They are as follows:

British India, Canada (a portion only), the Australian Commonwealth (six separate colonies), New Zealand, the four South African colonies, Austria, Hungary, Belgium, Brazil (a portion only), Bulgaria (a portion only), Chili, Columbia, Costa Rica, Cuba, Denmark (a portion only), France (a portion only), the German Empire, Greece, Holland, Honduras, Italy, Japan, Luxemburg, Newfoundland, Nicaragua, Norway, Portugal, Roumania, Russia (a portion only), Servia, Siam, Spain, Sweden, Switzerland, and Turkey (Asiatic). In some cases, as is indicated in this list, a portion only of some of these countries' railway system is under the control of the State.

Political, strategical, and financial considerations have been the principal factors which have influenced the State to retain control of the railway systems. Great military powers like Germany, Russia, Italy, the Indian Government, etc., must of necessity be in a position at any moment to control the traffic on the main arteries of the railway systems which connect the principal centers of commercial activity with the boundaries of the country. To be able to ship troops and war material along these lines without consideration as to ownership, rates, etc., is a sine quâ non where interests of great importance are at stake, and it is therefore essential that the responsible governing authority should in times of peace make every provision for this eventuality, whether the necessity to do so arises with a neighbouring power or from internal dissension.

The inefficient services in some countries by private enterprise have also contributed to the nationalization of railways, while a further reason for this step has been the undoubted difficulty of raising capital from private sources wherewith to construct the track, etc. Take the example of the Australian colonies: It is doubtful if the railway system would have grown to the extent it has done if the capital for the railways had had to be raised for rail-

way purposes alone; but with the credit which the separate governments can pledge as collateral security for the payment of interest and the power of taxation possessed by each State, it has been possible to raise the very large sums which are represented in the capitalized value of the railways in Australasia.

The necessity to "foster" the staple industries of some countries by the extension of railway facilities is another reason for State ownership, such as, for example, in Belgium and Norway, where there are numerous *lignes vicinales* in connection with the main lines. Examples of purely strategic lines are the Russo-Siberian and the Hedjaz (Asiatic Turkey) railways.

The general principle that railway traffic should be carried out under statutory authority is accepted by all, but in the application of the principle there is considerable divergence of practice. In Great Britain, the United States, Argentine Republic, Canada, Brazil, and Mexico (the three latter, with slight exceptions, noted hereafter), Rhodesia, Egypt, and Spain, the State has granted permission, under statutory obligations, to private enterprise to construct and work railways. In Great Britain the franchise is burdened with the costly process of land purchase, but in other countries the concessionaires of the railways have always been endowed in the first instance with more land for the railway track and its appurtenances than was absolutely necessary, but of recent years increase of traffic, population, and the value of land have now somewhat curtailed these privileges.

The countries where nationalization has been carried out may be broadly divided into three classes, viz., those where:—

(1) Railways are entirely owned and operated by the State;

(2) Railways are owned by the State and operated by private enterprise, and

(3) Railways where State aid towards construction or operation has been given.

In the first class are:—

British India.
Canada (a portion only).
Australian Commonwealth (six colonies).
New Zealand.
South African colonies (four).
Austria.
Belgium.
Brazil (a portion only).
Bulgaria (a portion only).
Chili.
Columbia.
Costa Rica.
Cuba.
Denmark (a portion only).
France (a portion only).
German Empire.
Hungary.
Honduras.
Italy.
Japan (process of ownership not quite completed).
Norway.
Portugal.
Roumania.
Russia (a portion only).
Servia.
Siam.
Sweden.
Switzerland (process of ownership not quite completed).

In the second class are:—

Newfoundland, Holland, Nicaragua, Brazil, and Bulgaria.

In the third class are:—

Denmark, France, Greece, Luxemburg, Russia (a portion only), and Spain.

Taking each class by itself, it is interesting to note the different characteristics belonging to the particular country under review. In India the railway system owes its inception to the guarantees given to private enterprise by the British Government for strategical and commercial purposes. The Indian Government now owns all the lines on British territory, having purchased the last of the guaranteed lines in 1906. The majority of the native State railways outside the above are

owned by the native chieftains and their governments, and leased to companies mostly financed with British capital. On the Indian State Railways the rates of carriage for passengers and goods traffic are very low; in many instances third-class passengers can travel five miles for one penny.

The Canadian systems of State-owned railways are due to the action of the Nova Scotian Government in building a line from Halifax to the Bay of Fundy in 1858. Extensions to this line and the building of the Prince Edward Island Railway (261 miles) were all included as part of the property of the Canadian Federation in 1867, the latter province being admitted to the confederation in 1874. Since 1901 the Canadian Government has constructed a State line in Ontario. The principal railway traffic in Canada is, however, in the hands of the Canadian Pacific and Grand Trunk Railway Companies and their allied lines, which, in most cases, enjoy a Government subsidy to assist in opening up the country.

The Australian colonies and New Zealand own and operate practically the whole of the railways in each colony. There are a few privately owned steam railways and tramways, but these are purely local. The particulars as to length of line, etc., are given in the table. It is obvious that the rapid growth of the railways in the different colonies is to keep pace with the development of farming lands and the settlement of colonists.

In the South African colonies, since the last Boer war, the railways have passed practically entirely into the hands of the Government. This does not, of course, apply to Rhodesia, where the railway companies are guaranteed interest and practically controlled by the Chartered British South Africa Company.

The great European nations of Russia, Germany, Austria-Hungary, and Italy have practically nationalized the whole of the railway systems within their borders. In Russia there are still approximately 12,700 miles out of a total of 39,418 miles which are managed or leased to private companies on certain concessions, but out of a total capital of about £107,000,000 which these 12,700 miles represent, the Government guarantees the interest on no less than £93,000,000, which means that practically the Government is the owner of the lines. The nationalization of Russian railways commenced in 1881, and has been gradually extended, so that now the State directly controls the enormous total of over 28,000 miles of line and has incurred liabilities on capital account of over £401,000,000.

Prior to the Franco-German war the railways in the different States forming the German Empire were in the hands of private companies. Since 1880 the process of acquisition of these lines by the State has been rapid, and by 1904 all the railways in Prussia, Saxony, Hesse, Bavaria, Wurtemburg, Baden, Oldenburg, Mecklenburg, together with the lines in Alsace and Lorraine, were entirely owned and operated by the German State Railway Department. The Grand Duchy of Luxemburg is not included in the above, as by an agreement made in 1902 the lines passed under the direct control of the German Government, and by 1959, on completion of a series of payments, the whole line will then become the property of the German State Railway administration.

In Austria and Hungary the Government commenced in 1876 acquiring such railways as were constructed by private enterprises prior to this date, and by the end of 1905 the whole of the railway system in the country had passed into the direct ownership and control of the Government.

In Italy the railway administration has suffered various vicissitudes. Originally established in 1839 by a line from Naples to Portico, the difficulties of arranging through routes and obtaining reasonable concessions

were due in a large measure to the fact that there were no less than eight separate Kingdoms or States in the country now generally called Italy. On the consolidation of these eight States into one Kingdom in 1860 there were at that time 1,359 miles of track under the control of four companies. A large number of the above had been built either by State money and the line leased, or by State guarantee of interest on private capital. Owing, however, to the economic condition in which Italy found itself at this time, the control or ownership by the State had practically been shelved for the time being. By 1870, however, the country having become more settled, the Government then turned its attention to the railway question, and by arrangement with three of the companies, the State assumed full control and then re-leased the railways to the companies. In 1906 the whole of the lines passed into the control and direction of the State on certain terms of purchase, which include an annual rental to the existing shareholders for sixty years, after which the Government is the absolute owner of the railway system. The results of nationalization have not yet been felt from the point of view of relief to taxation, but the enormous industrial developments of Northern Italy, the application of electrical traction supplied through the agency of the numerous hydro-electric power stations (for which Italy is becoming famous), are the factors which will tend to help in the reformation of what was at one time a notoriously badly managed railway system.

The Belgian Government commenced in 1857 to acquire railways, and, at the end of 1905, owned or controlled 2,490 miles.

The ownership of railways in Norway is curiously divided. There are three classes:—

(a) Entirely owned and controlled by the State;

(b) Owned by the State and the Communes through which the lines pass, and by private persons, and the whole worked by the State; and,

(c) Entirely private railways subsidized by the State.

In the first class, the State has contributed the cost of building the lines, but the local authorities through whose districts the lines run have had to provide the land, so that in reality the State and the Communes are joint owners; the latter, it is assumed, deriving an indirect benefit from the existence of the railway and rates levied for goods and passengers.

In the second class, which includes the main line, the Government has provided by far the largest portion of the capital, but, in order to attract capital, have agreed that local authorities and private persons may be directly interested in the capital expenditure and the net profits due to working, though it is assumed that they have no control over the State Department which operates the traffic. In no case does the interest exceed 4 per cent. on the ordinary share capital, nor is the private capital so invested large, being roughly 10 per cent. on the total amount expended.

The Portuguese State Railway system is not a large one, as can be readily understood, and has only increased from 105 miles in 1869 to 540 miles in 1905.

The Servian State Railways had their inception as the result of the famous Berlin treaty of 1878. In addition to the ordinary standard-gauge lines, the Government has constructed a large number of "light railways" of narrow gauge, which are to be opened in 1909.

The Swedish Government is the direct owner of 2,609 miles of line, of which over four-fifths have been constructed by the State.

The railway system in France is in a curious tangle. The Government owns and operates one line about 1,812 miles long (district of Chartres, Nantes and Bordeaux), but it is unable to give through tariffs to

COUNTRY.	Year.	Length State-Owned and Managed Lines.	Length State-Owned and Leased Lines.	Capital State-Owned and Managed Lines.	Capital State-Owned and Leased Lines.	Capital per Mile.	Total Revenue.
		Miles.	Miles.	£	£	£	£
India (Lines in British Territory.)	1905	20,722.15	......	252,196,195	......	12,170	22,855,231
India (Lines belon'g Native States).	1905	2,776.18	......	8,133,900	......	2,930	796,932
Canada	1906	1,444.92	......	16,699,072	......	11,556	1,571,232
Prince Edward Island	1906	261	......	1,483,218	......	5,682	52,883
Ontario	1906	138	......	1,961,925	......	14,217	113,337
Newfoundland	1906	......	636.88	......	2,372,208	3,724	86,026
New South Wales	1906	3,390	......	43,626,063	......	12,869	4,234,791
Queensland	1906	3,137	......	23,821,990	......	7,593	1,534,870
South Australia	1906	1,745¾	......	13,610,520	......	7,799	1,349,765
Tasmania	1906	462½	......	3,926,713	......	8,499	241,188
Victoria	1906	3,398	......	41,388,299	......	12,180	3,787,619
West Australia	1906	1,612	......	9,965,940	......	6,181	1,634,444
New Zealand	1907	2,458	......	22,498,972	......	9,153	2,624,600
Cape Colony	1906	3,074	......	30,642,453	......	9,968	3,772,770
Natal	1906	1,023¼	......	13,660,761	......	13,353	2,029,683
Transvaal & Orange River Colony	1906	......	......	23,339,335	......	......	5,284,672
Austria	1905	5,078½	......	111,791,005	......	22,010	12,224,367
Hungary	1906	......	......	100,883,487	......	......	11,843,073
Belgium	1905	2,490	......	88,326,000	......	35,472	9,718,073
Central Brazil Railway	1906	1,004	......	12,775,000	......	12,770	1,947,294
Brazil, Rio de Ouro Railway	1905	74	......	185,600	......	2,508	14,403
Brazil, West of Uinas Railway	1905	728	......	910,000	......	1,246	109,080
Brazil, Donna Christina Railway	1905	72	......	406,000	......	5,639	6,720
Bulgaria	1905	780	......	6,598,664	......	8,459	444,976
Chile	1906	1,592	......	8,400,000	......	5,283	1,240,252
Colombia	....	24	......	200 000	......	8,377	36,000
Costa Rica	1906	60 (4 R'ys)	......	825,290	......	13,754	21,520
Cuba	....	68	......	......	......	......	......
Denmark	1906	1,137	......	10,555,000	......	9,283	2,083,331
France	1905	1,727	......	39,173,028	......	22,682	2,152,865
Germany	1904	30,903	......	665,406,808	......	21,534	116,218,698
Italy	1907	8,216	......	226,254,000	......	27,538	16,996,431
Japan	1905	1,461.38	......	15,514,535	......	10,615	2,183,425
Japan (Private Railway)	1905	3,232.8	......	24,582,500	......	7,614	3,808,948
Netherlands	1904	......	1,102½	......	27,499,711	24,954	......
Norway	1906	313	......	2,698,927	......	8,622	139,996
Portugal	1905	540	......	7,759,000	......	15,836	576,000
Roumania	1905	1,975	......	35,464,228	......	17,956	2,309,680
Russia	1902	24,260	......	379,855,936	......	13,264	46,593,111
Servia	1905	336	......	5,041,588	......	15,004	332,515
Siam	1906	357	......	2,346,950	......	6,574	185,383
Sweden	1905	2,609	......	26,299,789	......	10,080	3,007,522
Switzerland	1905	......	......	12,052,032	......	......	4,827,092

Revenue per Mile.	Working Expenses.	Ratio Working Expenses to Revenue.	Gross Profit.	Interest, Etc.	Profit After Interest Charges.	Capital Repaid.	Special Expenditure on Revenue Account.	Remarks.
£	£	%	£	£	£	£	£	
1,102	10,889,612	47	11,965,619	9,645,477	2,320,142	7,576,397	......	
287	387,146	48	409,786	......	......	......	......	
1,087	1,558,505	99	12,727	......	......	......	......	
202	60,435	114	Loss, 7,602	......	......	......	......	
821	75,519	66	37,818	......	......	......	......	
135	112,729	131	Loss, 26,703	......	......	......	......	
1,249	2,308,384	54	1,926,407	1,541,427	384,980	433,019	......	
489	863,356	56	671,524	881,414	Loss, 209,890	......	......	
773	764,385	56	585,380	......	......	......	......	£103,304 should be added to Revenue on Account of Expenditure on rolling stock charged to Working Exp.
522	172,601	71	68,587	148,263	Loss, 79,676	......	......	
1,114	1,999,023	52	1,788,904	1,472,397	316,507	......	117,542	
1,013	1,201,753	73	432,691	348,467	84,224	746,852	......	Included in Working Expenses is expenditure o £39,016 of a capital nature.
1,067	1,812,482	68	812,118	......	......	......	......	No cap. charges paid out of rev. profits paid into cons. rev.
1,227	2,981,350	79	791,420	......	......	......	......	£2,732 capital paid out of revenue.
1,984	1,260,863	62	768,820	455,672	313,148	......	......	Sinking fund, £64,903.
......	2,927,875	53	2,356,797	1,442,030	914,767	......	......	Sinking fund, £584,340.
1,821	9,247,716	75	2,976,651	= 2.66%	......	......	......	In 1907 estimated deficit was £2,667,424, all deficit made up by State.
......	7,477,622	63	4,365,451	......	......	2,421,442	......	
3,902	6,211,710	63	3,706,362	3,333,790	372,572	549,322	......	T'l capital repaid £10,827,238.
1,947	1,879,838	96	67,456	......	......	Nil.	......	Only during last few years any profit.
194	32,030	222	Loss. 17,627	......	......	......	......	In 1905 £11,100 spent on permanent way. Always been worked at a loss (until recently) nearly six times its revenue.
149	117,073	107	Loss, 7,993	......	......	......	......	This railway will eventually be leased.
93	24,889	370	Loss, 18,169	......	......	......	......	
570	302,528	68	142,448	......	......	......	......	No statistics available to show any contributions to sinking fund.
780	1,417,510	114	Loss, 177,258	......	......	Nil.	......	Rate of exchange $20 = £1.
1,500	18,000	50	18,000	......	......	......	......	
358	23,171	107	Loss, 1,651	......	......	Nil.	......	
......	......	.....	......	......	......	......	......	Only one railway of 40 miles in operation and has been leased to private parties. No figures available to show result as regards revenue, working exp's, profit or loss or whether any cap. repaid.
1,832	1,685,278	80	398,053	......	......	......	......	Profit generally equal to 3 or 4% on capital.
1,246	1,557,011	72	595,854	......	......	......	......	
3,700	73,385,314	63	42,833,384	= 6.34%	......	......	......	
2,068	14,965,607	88	2,030,824	= less than 1%.		......	......	
1,494	965,324	44	1,218,101	= 8.3%	......	......	......	
1,178	1,731,870	45	2,077,074	= 8.5%	......	......	......	
......	......	.....	......	......	......	......	......	The State receives £329,166 as rent from the two companies who work railways. Also ½ of net profits after 4% on the paid-up capital of companies is paid. This amounted to £9,624 in 1905.
447	100,255	71	39,741	......	......	845,761	......	There are also 1,041 miles of railway that are worked by the State and owned by it together with communes and private persons. The capital cost amounts to £8,013,485.
1,066	329,000	58	247,000	= 3.1%	......	......	......	Net revenue after meeting Government railway bonds is estimated at £166,000 or rather more than 2.1% on capital of £7,662,000.
1,169	1,563,200	67	746,480	......	......	......	......	
1,556	33,407,903	71	13,185,208	16,673,992	Loss, 3,488,784	......	......	At end of 1904 mileage was 26,764 miles and tota capital expenditure £401,377,938.
989	174,162	52	158,353	241,140	Loss, 82,787	......	......	
519	......	36.9	68,425	= 5.13%	......	......	......	After deducting 10% of net earnings for renovation and extension fund.
1,152	2,160,418	71	874,104	......	......	......	......	
......	3,206,276	66	1,620,816	......	......	......	......	In 1905 the amount paid to sinking fund was £208,437.

Paris from these districts (except in very exceptional instances), owing to the competitive and State subsidies which the competing lines of the Orleans and the Ouest Railway Companies enjoy. The most extraordinary circumstances to be noted in this respect is the fact that, though the State owns and operates this particular line, its operations are stifled by a State-subsidized competitor. It would require more space than is at the disposal of this article to give a history of the position at various dates of the railways in France, but the whole question was settled in 1883 after many vicissitudes, on the following basis:—

The State was to resume possession of the whole railway system, rolling stock, etc., etc., at various dates between 1950 and 1960, and in the meantime the net profit each year was to be divided into:—

(1) The necessary amounts for mortgage bonds, debentures, etc., advanced by the State;

(2) A fixed dividend on the share capital; and

(3) A sinking fund to redeem the share capital.

If the net profit was insufficient to meet these charges, the State provided the difference. If in any year there was a surplus, then it went to the State under certain conditions.

The Swiss Government was authorized by direct mandate in 1898 from the public to acquire the whole of the main railway systems (five in number). The purchase price amounted to £12,000,000 sterling for four of the lines, and the fifth (St. Gothard) will be purchased in 1909. The improvements in rolling stock, service, and general personnel on the Swiss Railways since the Government took charge are obvious to those who have had experience before and after the change of ownership.

Turning to the American continent one finds that in Brazil, Chili, Costa Rica, and Colombia the State owns certain lengths of railway, which is, as a rule, administered at a loss, though the lengths of line and amounts so involved are comparatively trifling compared with the other interests involved in these countries. No reliable data as to the lines in Honduras, Guatemala, and Nicaragua are obtainable.

No observations on the subject of nationalization would be complete without reference to Japan and Siam. The latter country has shown what can be done by careful attention to details. The Siamese Government has managed to build up a small railway system of 357 miles out of the ordinary revenues of the country, and, after allowance of 10 per cent. each year on the capital employed, as a reserve for depreciation, etc., the resultant profit pays 5.13 per cent. on the capital employed. It does not follow that this result will, however, be always obtained, as there is no doubt that with the development of commerce in Siam a demand will arise for cheaper freight tariffs, etc., etc., which will have the effect of increasing the ratio of working expenses to receipts, at present only 37 per cent.

Since the Russo-Japanese war, Japan has set itself the task of acquiring the railway system, which up to that time was practically owned by private enterprise. By an act passed in 1906 the Government is to purchase all the lines scheduled in the act (2,812) before 1915 on payment at the rate of practically twenty years' purchase in Government 5 per cent. bonds. When these lines have been acquired the Government will own about 4,300 miles of railway. It is anticipated that the loans required for this purpose will be entirely redeemed by sinking funds in thirty-two years, and thereafter the country will benefit to the extent of about £5,500,000 sterling.

In concluding this statement of the practice in many countries on the control of the railway systems one cannot refrain from making the observation that there does not seem to

be any hard-and-fast rule or any real data on which to proceed as to whether or not the railway system should fall into line with the telegraph and postal services. Germany is the only country where published results have so far justified the step, and it remains for other countries to emulate its example and publish complete accounts for comparative purposes.

The table on pages 292 and 293 shows particulars of the railways in the countries reviewed, with working results, etc., etc. These have all been compiled from the information given in the report referred to at the commencement.

A MODERN FLOATING HOTEL

THE NORTH-GERMAN LLOYD LINER "KRONPRINZESSIN CECILIE."

By Julius Grundmann

DURING the past few years there has been a continual succession of remarkably handsome passenger steamers put into service on the North Atlantic, this development resulting largely from the healthy rivalry between the Hamburg-American Line and the North-German Lloyd Company. Among these may be named such vessels as the *Deutschland,* the *Amerika* and the *Kaiserin Auguste Victoria,* of the Hamburg-American Line, and the *Kaiser Wilhelm der Grosse,* the *Kronprinz Wilhelm* and the *Kaiser Wilhelm II,* of the North-German Lloyd. One of the latest additions to this remarkable list appears in the *Kronprinzessin Cecilie,* which may well be selected as an example of the modern floating hotel, adapted for the highest class of service between Europe and America.

This vessel was launched in December, 1906, at the yards of the Vulcan Works at Stettin. The German Crown Princess, for whom the ship was named, performed the ceremony of dedication. After the launch the vessel formed an opportunity for the work of the artists and decorators to whom the ornamentation of the saloons and staterooms was entrusted, and, after a successful trial trip, the first transatlantic crossing was made, the ship leaving Bremen on August 6 and reaching New York on the 13th following.

The total length of the *Kronprinzessin Cecilie* from stem to stern is 706.5 feet, the maximum breadth 72 feet, and the distance from the upper edge of the keel to the promenade deck 52.5 feet, these dimensions being the same as those of the *Kaiser Wilhelm II.* The displacement, however, is somewhat larger, being 28,760 tons, giving a gross registered tonnage of 19,500 tons. The powering is also higher, the engines being of 46,000 horsepower, giving a speed of 23.5 miles per hour.

A volume might be written of the interior construction and ornamentation of this marine hotel, but space permits only a brief description to be given.

Three classes of passengers are provided for, in addition to the steerage, the third class being very popular, and it is probable that this class will be included in subsequent vessels. There are 297 first-class cabins, capable of accommodating 742 passengers; 109 second-class cabins, for 327 persons; and rooms of four to eight beds, for 740 passengers of the third class. These rooms correspond in character to those of first-class hotels in their various grades. The Imperial rooms and the apartments *de luxe* are practically small palaces; the engineer and the artist have worked together in harmony with remarkable results. Only the principal dimensions of these apartments were determined by the Lloyds, the furnishing and decoration being left entirely to the firms undertaking this portion of the work, and only German artists and workmen were employed. Classical and modern art may be compared in the various saloons, while the limitations of space compelled the artist to meet many problems not encountered in similar work on land.

On entering the vessel the large dining saloon attracts attention, and

JUST BEFORE THE LAUNCH, CHRISTENING THE VESSEL

the effective illumination provided by the large light shaft enabled the customary dark colours usually employed to be replaced by those of lighter hue.

This light shaft is ornamented in the style of the Florentine renaissance, fifteen separate columns supporting a cupola carrying a glass roof. The balustrades of the second floor are visible behind the columns, and in the middle of the four sides appear recumbent figures carrying bronze medallions of the German Crown Prince and Princess and their coats-of-arms. The decorations of

VIEW OF THE FIRST CLASS DINING SALOON IN THE KRONPRINZESSIN CECILIE.

KRONPRINZESSIN CECILIE AT SEA.

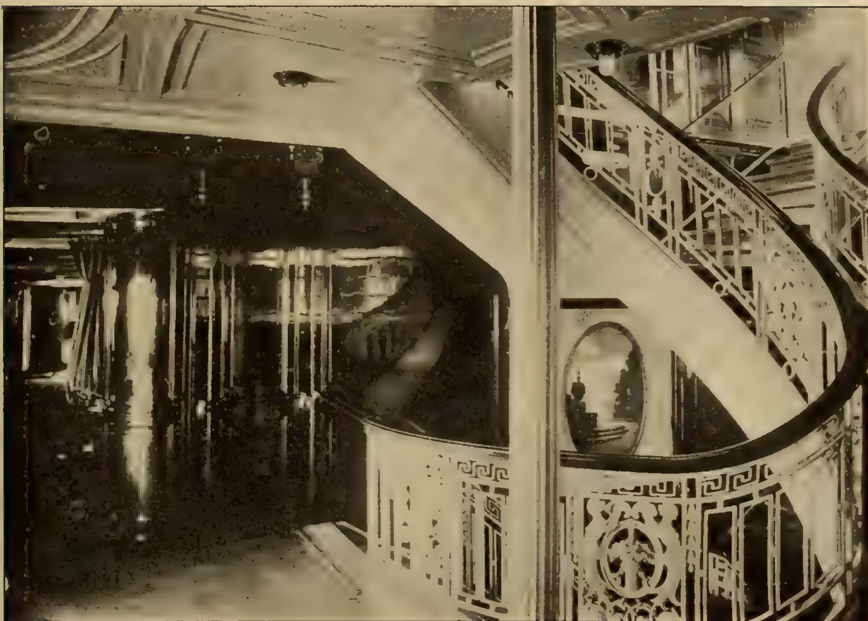
the walls of the dining saloon include paintings of landscapes, chiefly of Italian gardens. This large room contains seats for 512 persons, separate tables of various sizes being substituted for the usual long tables, except along the walls. In the middle of the room there are no fewer than 76 tables, arranged for two, four and seven guests, thus providing for families and parties of different sizes. The travelers have no longer to assemble at fixed times, summoned by the signal of bell or trumpet; but are free to take their meals at any hour, at any seat, and in such company as they choose. In this respect the dining saloon corresponds to the restaurant of a first-class hotel, and one may eat alone, at a two-seated table, or join any party which may be made up, and is not restricted to a table d'hôte menu, but can order at will from an extensive bill of fare. This applies to breakfast and luncheon, as well as to dinner, and such meals are all included in the price of the ocean passage, no separate charge being made.

From the dining saloon a magnificent stairway leads to all the decks of the first-class cabin. Here we pass the information bureau, corresponding closely to the office of a hotel, and where literature, tickets, etc., can be obtained at any time. The children's room adjoins the light shaft, and this is decorated and furnished to suit the taste of its small inhabitants. The long tables have low chairs, and the walls are covered with paintings representing scenes from the German fairy tales. From the vestibule one may pass to the book store, where all kinds of literature may be obtained, and the ladies' parlour is near by.

This room is decorated in the strict Empire style, and very handsomely furnished. The walls are covered with soft red silk, matching the carpet and upholstering, while on the wall is the large portrait of the Crown Princess Cecilie. The arrangement of the ladies' parlour is such as to afford many nooks and cosy corners, and the reading and writing-rooms are similarly planned.

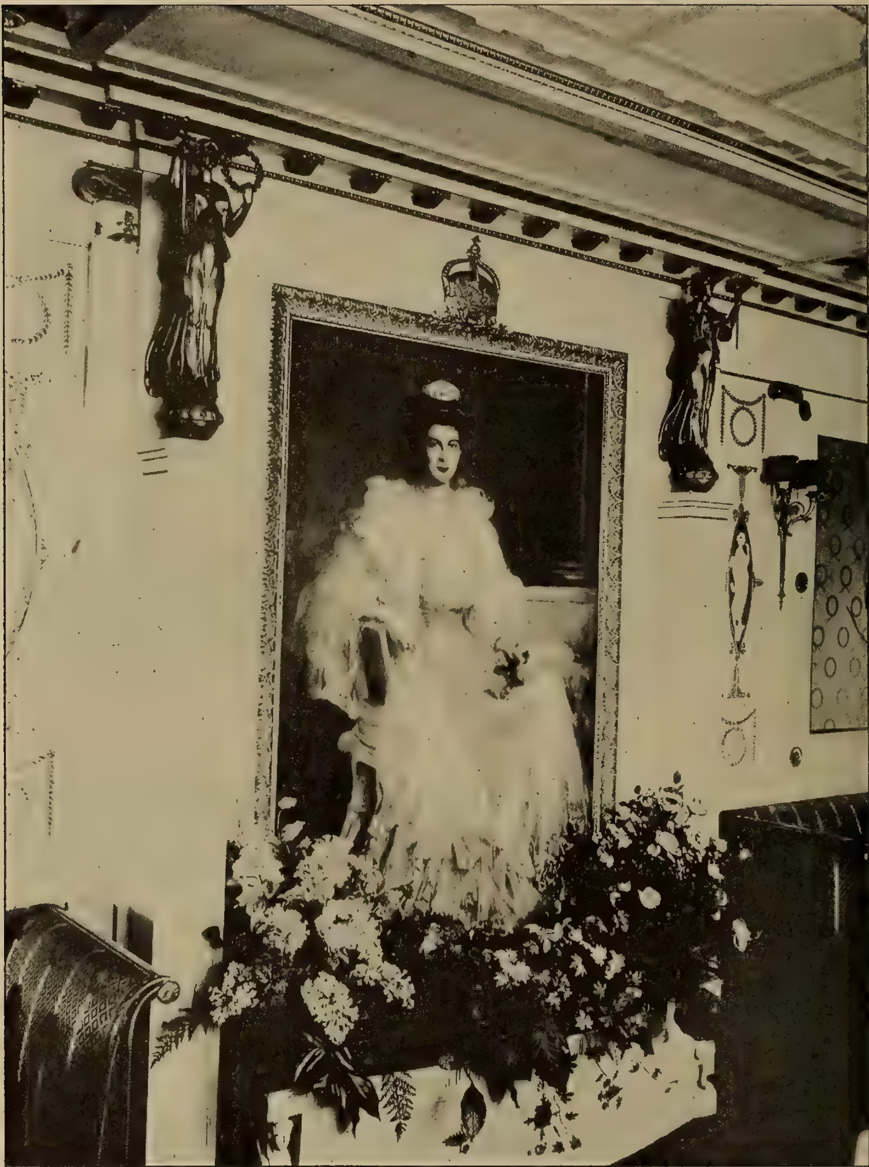
In addition to the usual smoking-room and café, there is a café provided for non-smokers, a convenience which many ocean travelers will appreciate. Many individuals enjoy the use of a café while at the same time they dislike the odour of tobacco. These rooms resemble more nearly the handsome places on the Paris boulevards than the smoking-rooms of earlier steamships. The café for smokers on the *Kronprinzessin Cecilie* is decorated in the Louis XVI. style, the walls being white and the upholstery of the furniture in green leather. The café for non-smokers is finished in style similar to the well-known establishments in Vienna, and there many hot dishes are served, and the place is almost like a general restaurant. The hangings are of green silk, and the panelling is of citron wood. The main smoking-room is a most comfortable room, especially arranged for the comfort of the occupants. It is surmounted by a cupola supported by columns, giving an excellent lighting, and, being decorated by yellow woods and illuminated by orange glass, a peculiar and pleasing effect is given. The chairs and divans are upholstered with a blue-green leather, giving a most effective contrast with the general illumination of the room. The walls of the smoking-room are decorated with paintings representing the castles of the various royal princes.

The staterooms for the passengers are of most luxurious design and equipment. Among these are included two imperial suites, containing bed chambers, saloons, parlours, breakfast-rooms and private baths. These suites contain the latest products of art and applied science, and include some very ingenious ideas. Broad sofas may be converted into berths for sleeping; washstands are concealed behind tables or chests of drawers, while a large wardrobe may



VIEW OF STAIRWAY LEADING TO DINING SALOON.

THE CHILDREN'S DINING ROOM ON THE KRONPRINZESSIN CECILIE.



PORTRAIT OF KRONPRINZESSIN CECILIE IN THE LADIES' PARLOR

be converted into a writing table. In like manner, a mirror is arranged to be turned down to form a serving table, and thus many articles are designed to serve for more than one purpose. The articles are all formed in costly materials, including copper, brass, bronze, mahogany, cherry and cedar. These staterooms are provided with electric heating apparatus, as well as bells, ventilators, electric lamps, etc. There are twenty-eight bathrooms available for the use of the passengers.

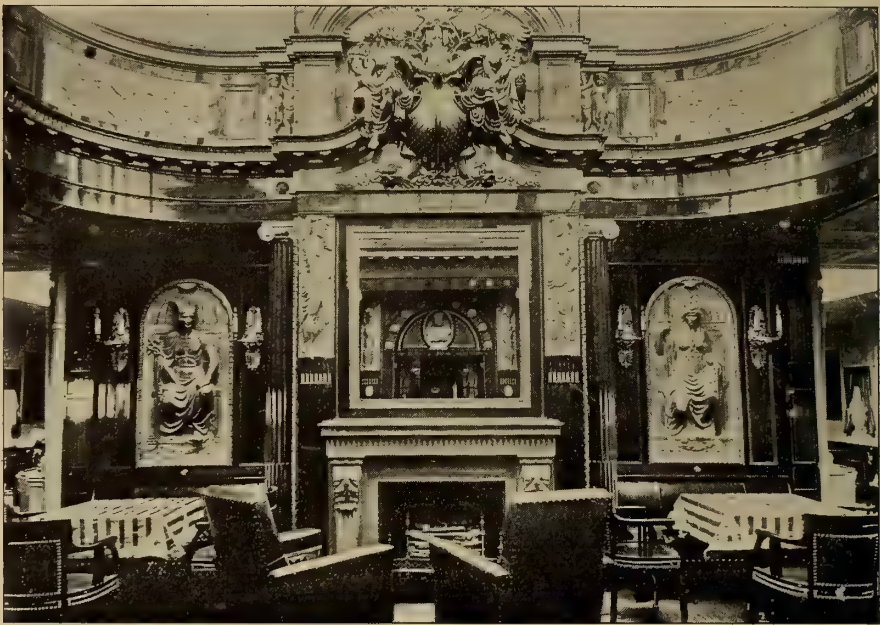
The arrangement of the decks of the vessel is worthy of attention.

VIEW OF THE LIBRARY AND READING ROOM.

CAFE FOR NON-SMOKERS.

These number seven distinct floors, and of these the middle promenade deck is 538 feet long, the promenade area covering 33,906 square feet. The hull of the ship is designed with especial regard to stiffness, and is composed entirely of material of German manufacture. There are nineteen boilers, with a combined heating surface of 107,643 square feet, and the fuel consumption is about 700 tons per day, forming the cargo of a respectably-sized steamer in itself. and the hull being fitted with bilge keels.

A most important feature in connection with this vessel is the ample provision of safety appliances. The hull is constructed with a double bottom, extending over its entire length, capable of holding more than a million cubic feet of water, and divided by bulkheads into twenty-six separate compartments. This double bottom is 6 feet 11 inches deep where it forms the support for the engines.



THE FIREPLACE IN THE SMOKING ROOM

The four funnels, which give such an imposing aspect to the steamer, are an indication of the fuel-consuming capacity of the furnaces.

There are four quadruple-expansion steam engines, driving two bronze screw propellers of 23 feet 7½ inches diameter, besides a number of auxiliary engines for driving the pumps, hoisting machinery, dynamos, etc. Notwithstanding the presence of this mass of machinery, there is little vibration perceptible, the main engines being balanced on the Yarrow-Schlick-Tweedy system The vessel itself is divided into nineteen water-tight compartments by means of seventeen bulkheads, besides which there is a longitudinal bulkhead in the engine room. These compartments are so proportioned that, even when two adjoining compartments are filled with water, the stability and buoyancy of the vessel are fully assured. The doors in the water-tight compartments are controlled by the Lloyd-Stone system, permitting any door to be operated from the bridge, while an indicator shows at once which doors

SALON OF A SUITE DE LUXE.

VIEW ON THE PROMENADE DECK, SHOWING THE WIND PROTECTORS.

are open and which closed. Seventeen steam pumps are available for emptying these compartments, with a combined capacity of more than 300,000 cubic feet of water per hour. These pumps take their steam from boilers situated in other compartments from those which they occupy, so that pumping may be effected even if the engine room should be flooded. Since the four boiler rooms are separated by water-tight bulkheads, steam is always available, even in case of a collision. The lifeboat service includes twenty-eight boats, besides a system of alarm bells and fire alarms distributed throughout the whole vessel. In addition to these, there is a complete system of fire mains, with hose and connections. In connection with this piping there is a complete sanitary drainage system.

As is the case with most of the later steamships, the vessel is provided with a wireless-telegraph system, permitting the publication of a newspaper with daily news, while the submarine bell signalling system is also installed for use in case of fog.

Such a floating hotel necessarily requires an extensive operative personnel. In addition to the captain, there are 24 officers, physicians and mail officials; 61 engineers and electricians; 231 stokers; 33 cooks, bakers and butchers; 9 barbers, baggage masters and booksellers; 33 scullions, and 59 sailors.

Thus we find combined in this great vessel all the equipment of a first-class modern hotel, together with the machinery and staff necessary for its propulsion across the ocean, the whole forming a tribute to the development of German mercantile marine.

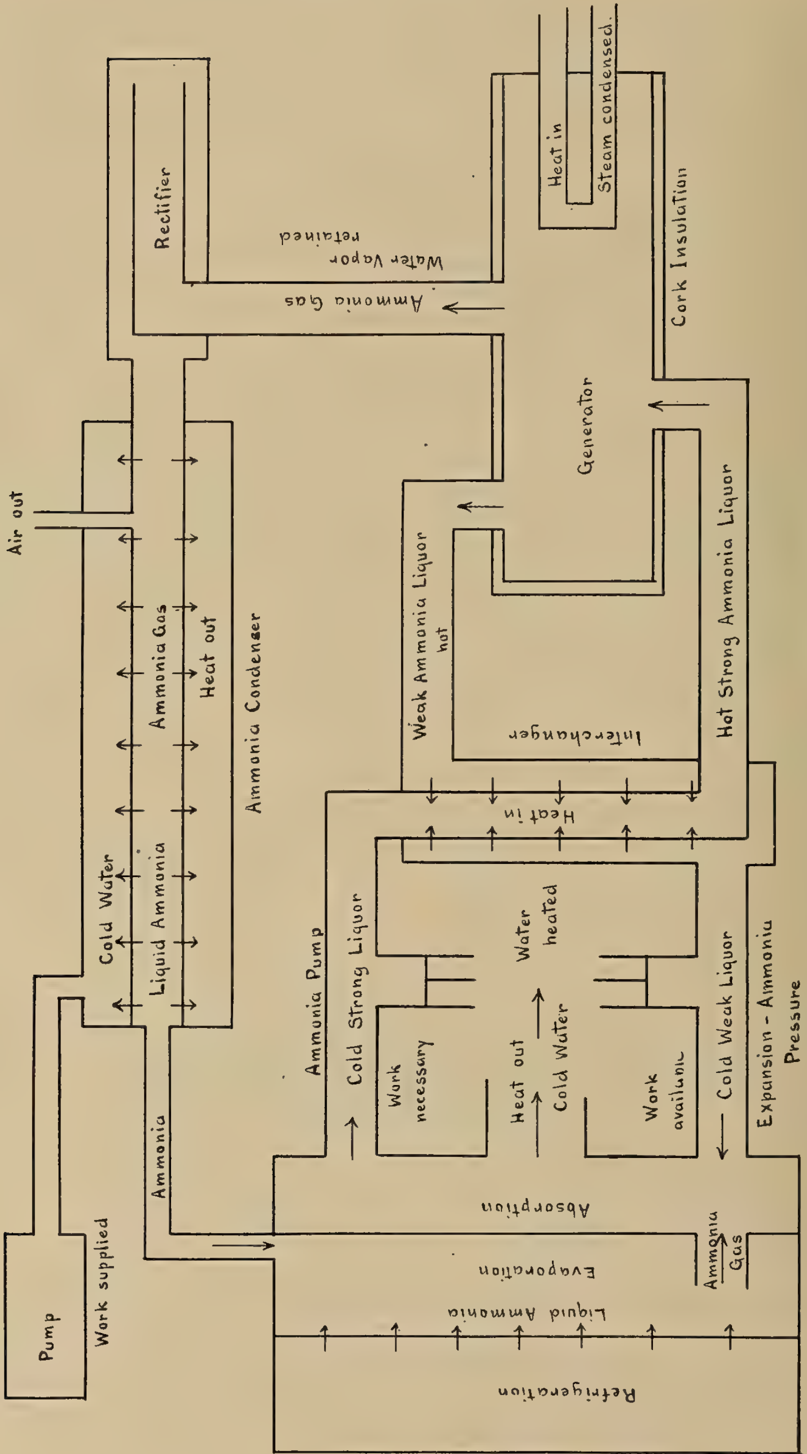
THE REFRIGERATING MACHINE AND THE GAS ENGINE

ANALOGY BETWEEN THE AMMONIA ABSORPTION MACHINE AND THE INTERNAL-COMBUSTION MOTOR

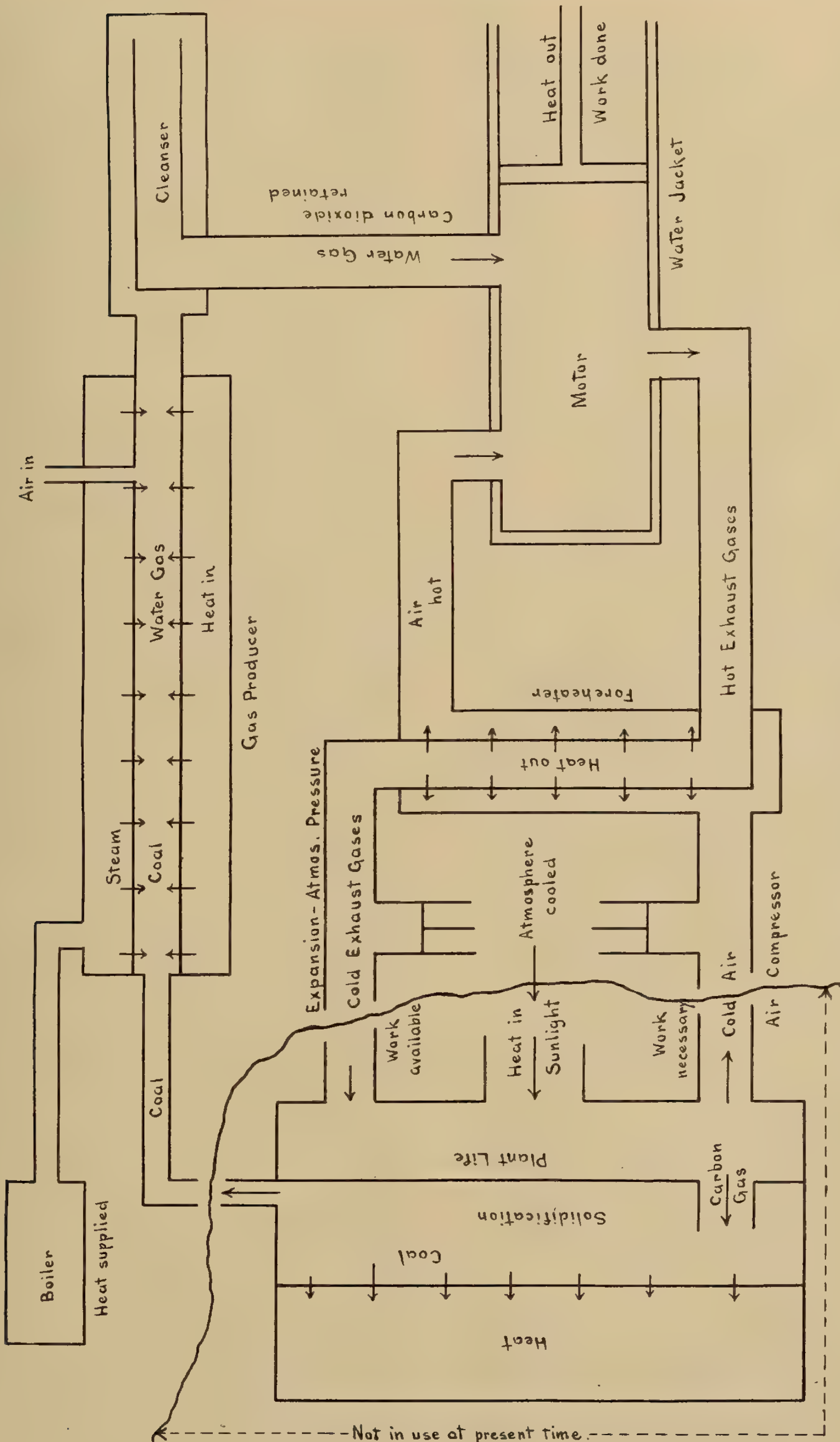
By Joseph H. Hart, Ph. D.

THE method of analogy, as used in studying the refrigerating machine in the light of our fuller and wider knowledge of power production, is of great help, not only in understanding the methods of refrigeration and the principles involved, but also in grasping the fuller knowledge of the real significance of the difficulties in connection with refrigeration and their position in the problem as a whole, together with suggestions in regard to their elimination or proper method of attack. Thus a study of the inter-relation between the steam engine and the compressor is of advantage, but its extension to a comparison of the entire heat theory with corresponding refrigeration conditions shows an almost complete analogue between the ammonia compression refrigerating machine and the production of power by the steam engine, and is extremely beneficial for a closer understanding of the two problems for both refrigerating and steam engineering specialists. It serves a further purpose, that in pointing out the difficulties and errors and the line of true development in the production of heat and power one can invariably, by analogy, arrive at the solution of corresponding problems in the theory of refrigeration.

This analogue and the advantages to be obtained by its examination holds, not only for the ordinary compression type of refrigerating machine in comparison to the ordinary reciprocating type of steam engine, but may be extended further in regard to the absorption type and shows an almost complete similarity between the action of the absorption system of refrigeration and the ordinary gas engine or internal combustion motor. This will doubtless appear as a matter of considerable interest to the average engineer in either field. The engineer in power production has been accustomed to believe that the internal combustion motor is comparatively simple in theory and practice and, on the other hand, it has been the consensus of opinion among engineers, almost as a class, that the absorption system of mechanical refrigeration has been extremely complicated and, until quite recently, very inefficient. That the absorption system of refrigeration is an almost perfect analogue of the internal combustion motor, when the process is carried through the complete cycle, is at once apparent from the consideration of the two diagrams here shown. Their diagrammatic form has been slightly altered in their practical constructive details in the two cases so as to become identical and augment the similarity, but the two diagrams as shown are identical, part for part, and their action is analogous or reciprocal in each individual unit. Thus, if the internal combustion motor is considered as a portion of a complete cycle, a large number of additional units must be installed. Again, the ordinary gas engine per-



AMMONIA ABSORPTION SYSTEM—REFRIGERATION PRODUCTION



INTERNAL COMBUSTION SYSTEM—POWER PRODUCTION

forms several duties of the entire process at once, or in succession, rather, and the tendency to-day in the more efficient installations is to isolate these separate duties and have them performed by individual units. Thus the average gas engine operates as an air compressor and as an ignition device, and as a power producer as well. If the air compressor is isolated in an individual unit and a heat interchanger installed as well, for the heating of the charge of air or gas before entrance into the gas engine, the analogue becomes more perfect. However, it involves the entire heat theory itself, and takes in the gas producer, and involves for its complete development a study of the preparation of the fuel itself under natural processes. However, the complete analogy becomes more apparent by a separate study of the individual units involved.

Thus, starting out at the motor of the internal combustion type and the generator of the absorption system respectively, they are identical but reciprocal in their action. In the gas engine motor two materials enter, the prepared fuel and air. They combine chemically with the evolution of heat, and one material goes out in the exhaust and the heat is used in the production of work. In the ammonia generator one material enters, a strong, hot ammonia liquor, composed of ammonia and water, and this is decomposed by the addition of heat in the generator and goes out in the form of weak ammonia liquor and ammonia gas respectively. The generator requires the addition of heat for its operation, whereas the motor performs its duty with evolution of heat. The heat in the motor can be used to produce work and can be obtained directly from external heat sources or by means of work theoretically. Not only is the analogy perfect from a theoretical point of view, but in practical detailed construction as well. High temperatures are equally objectionable in the two cases. The water jacket for the removal of the heat or the alleviation of the high temperature in the internal combustion motor finds its analogue in the use of cork insulation for the retention of the heat in the generator. The friction losses involved in the operation of the motor piston finds their analogue in the friction losses in the steam-heating pipes as well. The packing around the piston is equivalent to the steam connections in the generators, and the comparison is not merely a superficial one, since it extends into every phase of construction and theory. The incoming charges in the gas engine are hampered or limited in their efficiency by the presence of extraneous substances. The hot air contains nitrogen, which is in an inert gas and, theoretically at least, limits the efficiency. The water-gas contains carbondioxide and other impurities which affect the efficiency from both a theoretical and mechanical view-point. The hot exhaust gases also contain these impurities, and all of them carry off a portion of the heat both on ingress and egress. The same thing holds in the ammonia generator. The strong ammonia liquor contains a large quantity of unnecessary water apparently, and the ammonia liquid, which is not evolved from the strong liquid by means of the steam coils, stays in the weak ammonia liquor and acts practically as an impurity with a capability of heat conveyance on both ingress and egress. The ammonia gas, in turn, possesses impurities on account of the presence of water vapour and air and on account of the decomposition of ammonia gas into hydrogen and nitrogen by the heat processes.

The action of the rectifier, so called, in the ammonia absorption system and of the cleanser in the gas producer are identical. A portion of the heat is lost here in both cases, and a portion of the operating fuel or refrigerating material as well.

The ammonia condenser is almost

equally the analogue of the ordinary water-gas producer. In the condenser the ammonia gas enters a series of pipes surrounded by cold water, the heat passes out through these pipes and the ammonia gas is condensed. A cock for the removal of the air is installed at the upper part of the condenser coils and the cold water must be circulated by means of a pump to which work must be supplied. In the gas producer the action is reversed exactly. Coal is inserted and corresponds to the ammonia liquid, steam is injected and heat enters with a chemical reaction as well. Heat goes in and water gas is produced and the steam and heat supply produced by means of a boiler. Air also enters in the production of the water gas, and by a stretch of the imagination the analogy becomes perfect with the limitation only upon the relative amounts of the two ingredients involved.

The interchanger in the ammonia absorption system corresponds absolutely in its action to the installation of a fore-cooler in the gas engine system. In the latter the hot exhaust gases pass through double pipes through which the supply of air is also drawn. The heat leaves the hot exhaust and passes into the inflowing air, which may or may not receive this heat under pressure. The hot exhaust gases from the internal combustion motor then pass into the open atmosphere and contain some energy from which work would be available, if some process of condensation were possible analogous to the condensing engine. Work is wasted here, however, in addition, due to the fact that the average gas engine motor exhausts at from 30 to 40 pounds back pressure, and this represents a distinct waste. The analogous feature in the absorption machine is present in the inter-changer and the ammonia pump. The weak ammonia liquor, after giving up its charge in the generator, passes through the interchanger, consisting of double pipes, and gives up its heat to the strong ammonia liquor coming from the absorber. Both generator and motor operate most efficiently under comparatively high pressures, and the cold, strong liquor requires work upon it at this point by means of a pump to inject against the generator pressure, and this feature is analogous and reciprocated to the work obtainable from the exhaust of the gas engine

Again, the weak, cold liquor, after passing through the interchanger, exhausts, in the ammonia absorption type, into the absorber from the pressure of the generator to that present in the absorber, and work is available, at least theoretically, under these circumstances. On the other hand, in the gas engine system the cold air which is supplied to the motor is insufficient at ordinary atmospheric pressures and work is necessary by means of an air compressor to supply this under the pressures at which the gas engine motor operates most efficiently. An air compressor is here necessary, although the duty is often performed by the action of the internal combustion motor itself during a portion of its stroke.

The refrigerating end of the absorption machine finds no working analogue in the internal combustion motor. The processes involved in the latter in this phase are purely natural ones, although the analogy holds perfectly and the phenomena are carried out by natural agents. Thus, in the ammonia absorption system the ammonia liquid is injected through a suitable valve into the cooling coils, where it evaporates at a low pressure and absorbs the heat of vaporization from the surrounding bodies. The ammonia gas then goes into the absorption chamber, or the absorber, as it is called, and is absorbed spontaneously by the cold, weak liquor. Heat is produced at this point, and this heat must be carried out by means of cold water.

The analogous process in the internal combustion motor is a natural one absolutely and is involved in the production of cold from the exhaust gas of combustion. The cold exhaust gases are absorbed in plant life by means of the action of sunlight, which carries heat into them and the heat of decomposition of carbon and oxygen is absorbed at this point. This process is as much a process of refrigeration as that in the absorption system. What are known as the *cold May rains* to students of meteorology is a refrigerating process absolutely and occurs when plant life is at its maximum process of growth two or three weeks after vegetation is out, this refrigeration resulting in the condensation of large quantities of water vapour present in the air. The carbon separated from the oxygen then undergoes a process of solidification and transformation into coal with the evolution of heat into surrounding bodies, and this coal can then be supplied to the gas producer, making the process a complete one and absolutely analogous or reciprocal in every respect to the internal combustion motor.

A study of these two diagrams shows surprising results. The analogy is absolutely perfect and the difficulties involved in one system are always present in the other. Their importance, however, may vary within wide limits. Thus the presence of impurities in water gas is not an objectionable feature, and their presence in the hot-air charge is absolutely necessary. The presence of the impurities in the weak ammonia liquor is not objectionable but is a limitation on efficiency, whereas the presence of the water vapour and other impurities in the ammonia gas is very objectionable and unless its removal is accomplished limits the efficiency of the process and may result in its non-operation. All the developments possible in gas engine work, such as the injection of steam, delayed ignition and the water jacket, find their analogous and reciprocal problems in the injection of extra ammonia gas, more than the water can take care of, fractional distillation and insulating problems. The desirability and the efficiency resulting in the separation of the two duties of the motor, namely, power production and air compression, into two separate units is at once apparent, or, if more efficient as combined in the motor, possesses the desirability of an analogous development in the absorption type, and, in fact, attempts have been made to inject the cold, weak liquor by a process analogous to that involved in the steam injector, ammonia gas only being utilized. A further study of the two systems serves only to increase the remarkable similarity and analogy existing between them and almost any phase or development in one finds its complete analogue in the other.

THE INFLUENCE OF RECENT DEVELOPMENTS IN SIZE AND SPEED OF STEAMSHIPS ON PORT AND HARBOUR ACCOMMODATION

By Brysson Cunningham

THAT there have been of late years, and strikingly within the limits of the last twelve or eighteen months, very marked increments in the size and speed of new steamships is a fact which no one will venture to gainsay. Hardly has the press completed its laudatory comments on the introductory performances of the latest, largest and fastest vessels in the world, when it is again called upon to announce the inception of leviathans even more huge and powerful. Fresh records of size and speed have, in fact, been created only to be challenged and, no doubt, ultimately surpassed. And this cyclopean struggle for the supremacy in the mercantile marine is simply the indication of a general expansive movement extending throughout all grades of commercial vessels down to those of the lowest standard.

Remarkable indeed have been the strides made within the last decade in the art of shipbuilding, to say nothing of the astounding progress achieved during the comparatively short period which has elapsed since the introduction of steam power. We will not, however, indulge in retrospection beyond the year of grace 1898. Ten years ago the premier vessel in point of size was the *Kaiser Wilhelm der Grosse,* of the North German Lloyd. She had a length of 648 feet 6 inches, a breadth of 66 feet and a displacement of 20,880 tons. The *Mauretania* of to-day has a length of 790 feet and breadth of 88 feet and a displacement of 45,000 tons. The figures form a marked contrast, and they are worthy of more than a merely casual glance. Let us consider what they imply. In a period which is really less than a decade by several months the length of the leading steamship has increased nearly 22 per cent., the breadth 33 per cent. and the displacement considerably over 100 per cent. If we assume the same rate of increase to be maintained in the future, we should have in another ten years' time a vessel almost 1,000 feet long and 120 feet wide, with a displacement approaching 100,000 tons.

At first hearing, these figures may sound incredible, even to the verge of absurdity, but a little reflection will show that they are based on no mere idle speculation. Try to imagine how preposterous in 1898 would have seemed the notion of the creation of the Cunarders, now just entering upon careers which give every promise of the highest degree of success. At that epoch the *Lucania* and *Campania* were still in their prime, and represented the latest thing in English shipbuilding enterprise. To eyes which have beheld the *Lusitania* and *Mauretania* in all their magnitude, the dimensions of the older vessels seem of trifling significance. The *Lucania* was only 620 feet long—170 feet less than the *Mauretania;* she was only 65 feet broad—23 feet less than the *Mauretania,* and she had a displacement of 18,000 tons—no less than 27,000 tons less than the *Mauretania.* The whole scheme of the latest Cunarders, judged by the standards then existing, would have been pronounced fantastic and absurd.

Yet, fantastic or not, it has been realized, and is now a hard and in-

disputable fact. So also in 1918 no doubt we will accept in all equanimity and indifference two new sister ships of the Cunard Line, possibly the *Pennsylvania* and the *Transylvania,* with lengths of 1,000 feet each and 70,000 each gross tonnage. Such vessels will be some three to four times as huge as the ill-fated *Great Eastern,* pronounced less than half a century ago an unwieldy monstrosity created ages before her time. Even now we are promised by the White Star Line vessels of 860 feet in length, and of 45,000 to 50,000 tons.

As in size, so too in regard to rapidity of movement. The Atlantic speed record in 1898 was held by the English sister ships already mentioned, by the *Lucania* in point of fact, at 21.81 knots per hour. It was not, indeed, until the renaissance (or, shall we say, the birth?) of German shipbuilding in that year that the British supremacy was seriously challenged, but in June, 1901, despite the fact that the *Lucania* had by that date herself raised the standard to 22.01 knots, the *Deutschland* eclipsed all previous records with a speed of 23.51 knots, while the *Kronprinz Wilhelm* ran her exceedingly close with 23.47 knots. This speed remained the standard until towards the close of last year, when the *Lusitania,* by the achievement of 24.51 knots, retrieved the supremacy for the British flag. The *Lusitania* has since shown herself to be capable of another half knot. As for the *Mauretania* her ultimate capabilities are a matter of surmise. She did 27.36 knots during her trial runs, and though her best achievement in actual service hitherto has only been 24½ knots, yet it is manifest that this can hardly be recognized as a full display of her powers. It is worthy of note that speed records are by no means confined to merchant vessels. H. M. S. *Indomitable* has demonstrated the fact by averaging 25½ knots on the occasion of her recent voyage from Quebec. Altogether it is a fair statement to make that there has been an increase of 4 knots (18 per cent.) in the course of the past ten years, and it is quite within reasonable bounds to expect a speed of 30 knots in 1918. The voyage across the Atlantic will then undoubtedly be performed within four days.

Now, these facts and figures, while providing justifiable cause for wonder and admiration, are not without a serious side, and convey to the reflective mind a problem of some moment and no little concern, and the matter is one which possesses a very strong interest for those connected with shipping and the engineering pursuits allied thereto. Expansion is not a process which can be continued indefinitely in any branch of construction work, and even within the limits of practicability there are extraneous considerations which often intrude themselves, causing complications of no slight importance. One factor is, of course, the question of expense, the financial advantages and disadvantages attaching to vessels of large size and great speed. With this, however, we are not immediately concerned, nor do we intend to consider problems of naval construction involving the rigidity and strength of long steamships.

We propose to confine our observations in this article to that aspect of the subject which affects the accommodation of sea-going vessels at their several destinations. Shipbuilding and harbour construction are arts which have ever gone hand in hand. The ship for the harbour and the harbour for the ship—so it has always been since the inception of the science of navigation. And as the ship increases in size, so must the harbour increase in capacity.

Now, size is a matter of three dimensions, and in naval construction these dimensions are represented by length, beam and draught. Each of these factors exercises its own special influence on corresponding features in harbour development. As regards length, quays must obviously be provided having uninterruptedly straight

CHANNEL DREDGING WITH ORANGE-PEEL BUCKET. THE HAYWARD COMPANY, NEW YORK

frontages of extent sufficient to berth the largest vessels alongside. As regards beam, entrance locks and passages must be made wide enough (as also in the case of locks, long enough) to afford a reasonable margin on the dimensions of the largest ships using them. And as regards draught, the depth of water on sills, in entrance channels and fairways, as well as in inner basins and docks, must be ample, to allow sufficient clearance for keels of vessels to pass over or through them.

Of the three dimensions, two, length and breadth, present to harbour authorities perhaps less difficulty in the matter of treatment than the third. It is, comparatively speaking, easy—or, at any rate, not exceptionally difficult—to increase the lengths of quays and the widths of locks, even when they are already in existence, and to do so at an expenditure which is directly proportionate to the advantages gained and which also bears some such relationship to the cost of the original work. A quay 1,000 feet long costs approximately twice as much as a quay 500 feet long, and a lock 100 feet wide need not exceed double the amount required for a 50-foot lock. But this commensuration is not the case with deepening operations. Increments of depth in sills and passages, berths and entrance channels, can only be obtained in the majority of instances by an outlay which in many cases is almost, if not actually, prohibitive, and always constitutes a most powerful deterrent to any undertakings of that nature. For each and every additional foot in depth the expenditure increases in a ratio which is geometrical rather than arithmetical, and which soon reaches a limit beyond the financial resources of the locality.

Let us consider for a moment what are the definite requirements in first-class ports for the very near future.

(1) Entrance locks and graving docks must henceforth have lengths approaching 1,000 feet and breadths of from 100 to 120 or 130 feet. Newport (Monmouthshire) already has such a lock in course of construction. The overall length of the lock (1,000 feet) is subdivisible by an intermediate pair of gates, so as to form two chambers of 600 feet and 400 feet, respectively. The width of the lock is 100 feet. A scheme was recently on foot for providing the Liverpool docks also with an entrance lock 1,000 feet in length by 130 feet in width—the actual design shows a length of 870 feet. The largest graving dock in existence at the present time is the Canada graving dock, Liverpool, with a length of 925 feet 6 inches and an entrance width of 94 feet, but graving docks much larger than this have certainly been in contemplation. Tilbury graving docks, the largest in connection with the port of London, are 846 feet long. Glasgow has a graving dock 880 feet long. At Avonmouth, the new lock entrance is 875 feet long by 100 feet wide, and a graving dock is now being constructed to a length of 850 feet and a width of 100 feet. Portsmouth is about to have a lock 850 feet in length and 110 feet in width; Immingham, one of 850 feet by 90 feet. All these figures are in close proximity to the dimensions laid down above, and it is evident that if any foresight worthy of the name is to be displayed and any prudential provision for future requirements made, the lengths and widths of closed chambers for large seagoing steamships will henceforth be at the least 900 feet and 100 feet, respectively. They may exceed these figures with advantage.

(2) The depths of sills must be 40 feet below surface-water level. This depth is often attained now at high water of spring tides at several ports, for instance at Liverpool, where the range of tide is as much as 30 feet. But this arrangement only allows of intermittent accessibility, and to ensure a constant service it is desirable, where the range of tide is not excessive, as at New York, to make low-water level the datum line. Liverpool contemplates at no distant date

Photograph by courtesy of White Star Line, Liverpool.

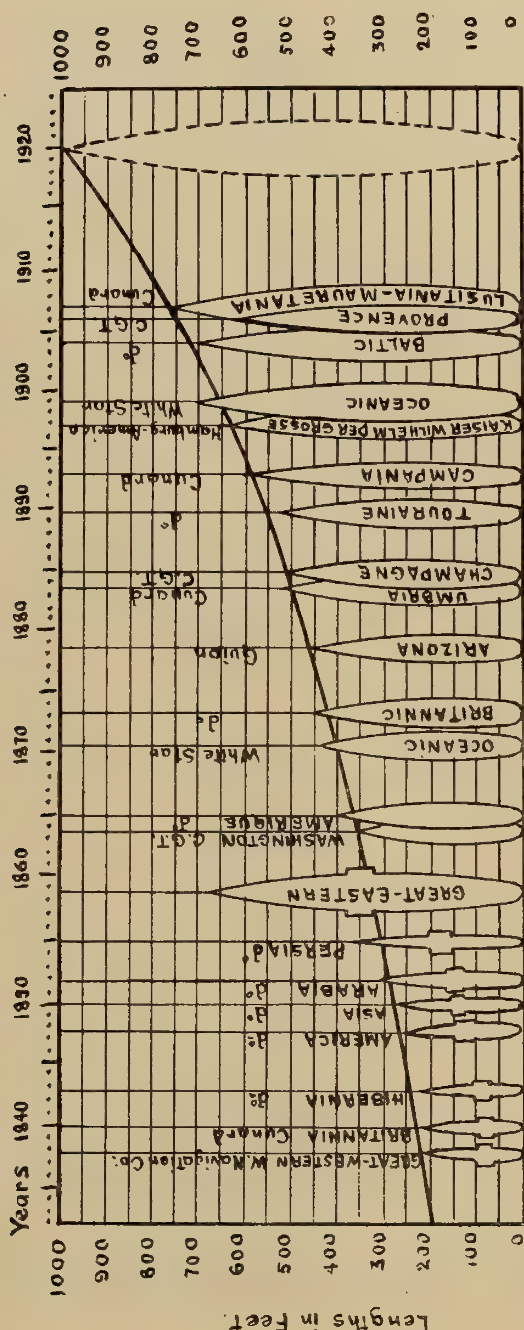
R. M. S. ADRIATIC AT LIVERPOOL LANDING STAGE

sills affording 40 feet of water at high water of neaps and 20 feet of water at low water of springs. The great expenditure involved in such a step precludes the attainment of a greater depth, even in the case of so powerful and wealthy a port, and the validity of this impediment has already been indicated.

Photograph by courtesy of White Star Line.

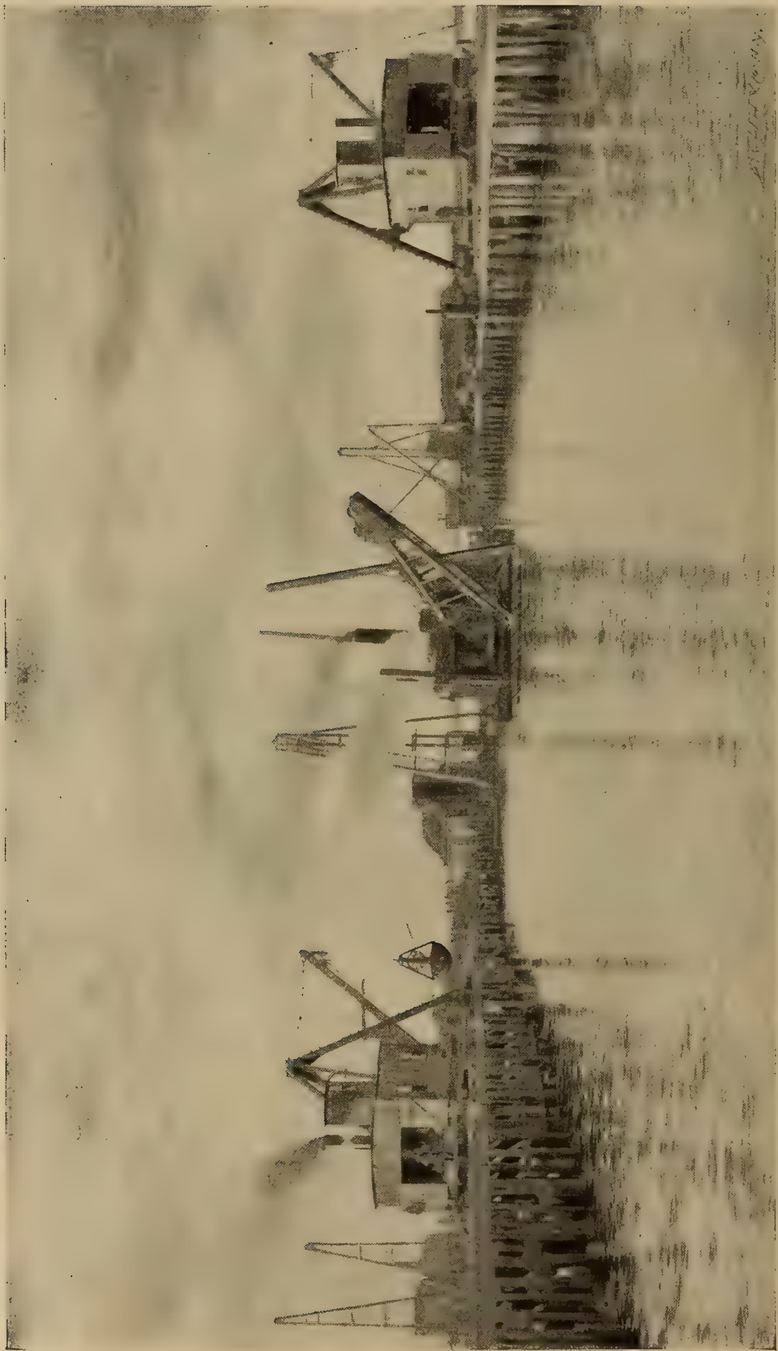
ANOTHER VIEW OF R. M. S. ADRIATIC AT LIVERPOOL LANDING STAGE

It has been very aptly pointed out that, except for the Atlantic and Cape trades, there is a very strong argument against the deepening of port entrances to the standard of modern shipbuilding. Traffic to the far East is mainly governed by the Suez Canal, as that to the far West will in time be ruled by the Panama Canal. The depth of the Suez Canal, which in 1898 was only 28 feet, and in 1902, 29 feet 6 inches, is now in course of being increased to 34 feet 6 inches, but some time must necessarily elapse before this last-named depth can be realized throughout. Even when it is realized it will be considerably below the demands of the largest vessels, and therefore a smaller class of steamships must be used for Oriental services, and their ports of call do not need to make provision in excess of the conditions prevailing in the Suez Canal. Yet, even in this case, the fact must not be overlooked that eastward trading vessels are not restricted to the canal route. Large cargo vessels can, and do, go round by the Cape, and where time is not of the highest importance, the longer journey is accomplished with economy and satisfaction. There can be no doubt, however, that in time the Suez Canal will be deepened to the 40-foot standard. Pressure of opinion already tends in that direction. The Panama Canal is to have



CURVE SHOWING INCREASE IN SIZE OF TRANSATLANTIC STEAMERS SINCE THE FIRST TRIP MADE BY A STEAMBOAT

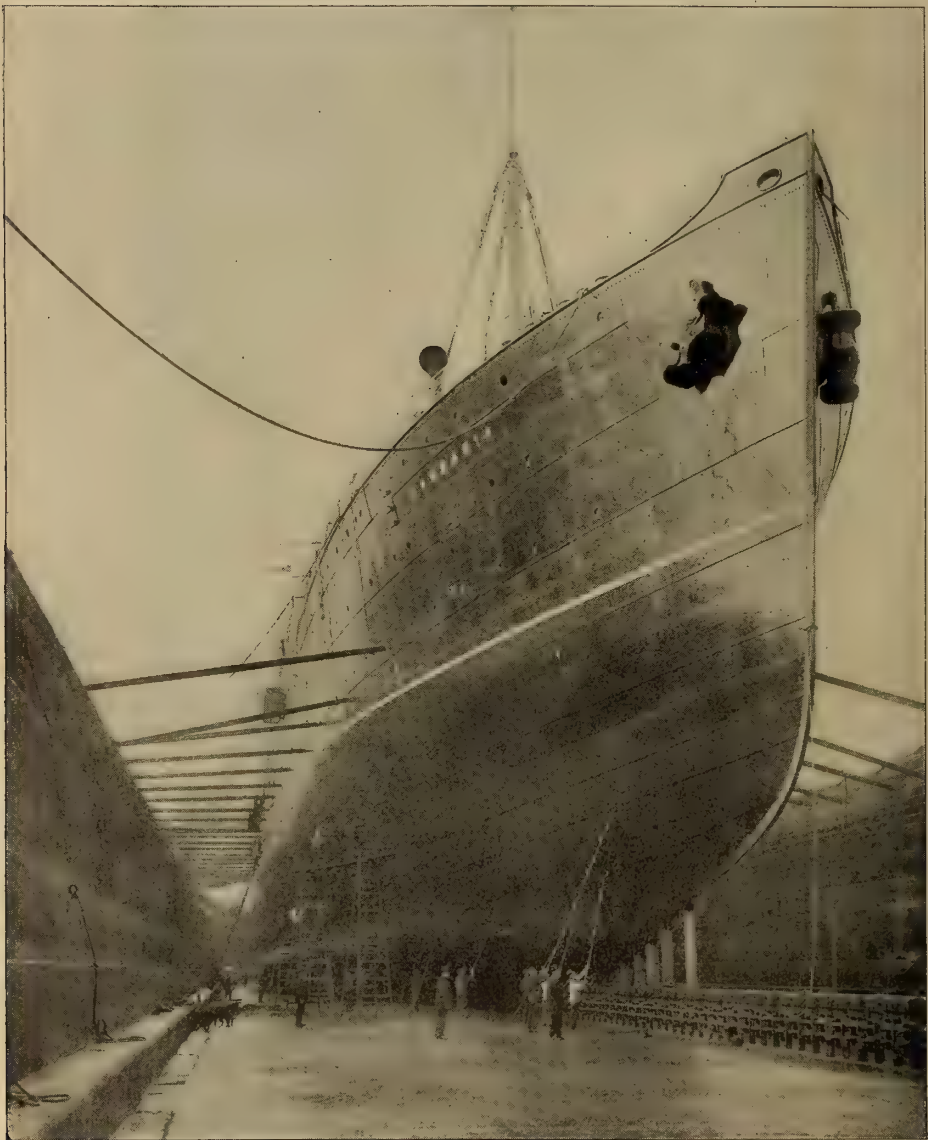
The diagram shows very strikingly how far ahead of the times the *Great Eastern* was. According to the curve, the year 1920 will see the 1,000-foot boat



HAYWARD DIPPER DREDGES EXCAVATING THE SITE OF THE NEWPORT NEWS DRY-DOCK

CONSTRUCTION OF DRY-DOCK AT NEWPORT NEWS, VA., SHOWING LIDGERWOOD CABLEWAYS

a depth of 40 feet, and New York harbour entrance is to be deepened to the same depth. The Ambrose channel at that port now has a ruling depth of 35 feet at low water, and dredging operations are proceeding rapidly.



Photograph by courtesy of Cunard Company.

CUNARD LINER CARMANIA IN CANADA GRAVING DOCK, LIVERPOOL

The difficulty, as has already been emphasized, in all cases of deepening operations is a financial one. The same remark applies in slighter degree, but no less essentially, to other features of port extension and development. It has, indeed, been urged that seaports cannot equitably be expected to undertake the heavy burden

of such operations from their own unaided resources, and that the matter being one of national importance, in that in maritime countries national progress is bound up in successful ships were built on national subsidies—why should not first-class ports be expanded on similar lines? The maintenance of naval supremacy depends on the efficiency of the national

Photograph by courtesy of White Star Line.

R. M. S. ADRIATIC IN CANADA GRAVING DOCK, LIVERPOOL

commercial operations over sea, there could be no stronger plea and no higher justification for state assistance. There is much to be said in favour of the proposition. The largest and fastest British steamharbour, and the decline and fall of any one of these would be a matter of grave national concern. "In my opinion," said Lord Pirrie recently, "when port authorities who have striven to provide and have provided

certain facilities are unable to incur the necessary expenditure for further development, it is desirable that the State should come to their assistance, and thereby aid these authorities in developing ports on national, rather than on local, lines." The statement is one which commends itself for earnest consideration.

As regards the question of speed, there is perhaps some difficulty in establishing a connection between recent advances in ship propulsion with the necessity for extension in port facilities and accommodation. At any rate, the connection is not obvious, and yet, on consideration, it cannot fail to become evident that a certain relationship does exist. It is idle for vessels to steam across the Atlantic at a rate of 25 or 26 knots an hour if they are going to be held up in the concluding stage of their journey by a low tide or a dense fog and an intricate channel. The delay occasioned by these impediments may be, and often has been, sufficient to nullify all the advantage gained by the maintenance of a high rate of speed and to render nugatory all the efforts made for an early delivery of mails and rapid dispatch of passengers. Hence, steps must be taken to minimize, and if possible, remove all such obstructions to favourable navigation. River bars must be lowered and navigable channels efficiently buoyed and lighted, as well as deepened, straightened and regulated wherever necessary. Such works are quite feasible. The Mersey bar, the crest of which in fifteen years has been lowered by 19 feet, is an excellent instance of what can be accomplished by steady and persistent effort. Antwerp is seriously contemplating the straightening of the Scheldt, and the Clyde has long been under treatment at the hands of the Glasgow authorities. At one time only available for vessels drawing 4 feet at low water, the bed of the Clyde has now been deepened to 28 feet, and presents practically a level bottom from Glasgow to the sea. Special dredging operations had, however, to be resorted to in order to enable the *Lusitania,* then drawing 29 feet 6 inches, to leave in safety the river into which she was launched.

The greatest evil and most relentless opponent of rapid locomotion on land or sea is fog. It is the most fruitful source of disaster, and it has baffled the ingenuity and science of modern days to find a remedy. Yet, even if fogs continue to hold sway, there is no reason why movement should be altogether fettered, in view of some recent achievements in sound signalling. By means of submarine sound signals (initiated within the last few years by a company in Boston, U. S. A.), which have been most successfully applied to the entrances of the river Mersey and of the harbours of New York and Cherbourg, it is now possible for vessels moving at a high rate of speed to locate accurately at distances of five and six miles the position of guiding stations and indicators. Over one hundred steamships are now fitted with the receiving apparatus, which consists of microphones set in tanks of sea-water at each side of the bow, and connected by a telephone with the chart house or bridge.

The warning bell of a buoy or lightship is struck several feet below the water-surface level, and the sound reaches the ship on the quarter from which it comes, so that by a little manœuvring the position of the signal is determined. Until fogs are a thing of the past, this ingenious apparatus will be of immense utility to navigators in approaching their destinations.

It is abundantly evident that developments in ship construction and harbour accommodation must keep pace with one another. Had there been a dock suitable for the reception of the Great Eastern, we have it on the authority of Lord Pirrie that the career of that unfortunate vessel might have been entirely different, and unless adequate accommodation is forthcoming for modern vessels of a much more colossal type, the same

THE CUNARD TURBINE STEAMER LUSITANIA PROCEEDING DOWN THE CLYDE FROM THE YARDS OF JOHN BROWN & CO., LTD., CLYDEBANK

The picture shows well the difficulties encountered in handling a boat of this size in a comparatively small river.

absence of facilities for their effective utilization will inevitably lead to results as disappointing. Many vessels at the present day cannot load down to their proper load line for want of adequate depth of water at their home ports, and this indicates a condition of things which calls for prompt remedial measures. A great responsibility rests with port authorities, and it is unfortunate that they are so often hampered in their efforts by a lack of funds. Ultimately the power, of course, lies in the hands of the citizen, who should see to it that as far as possible a free hand is given to those who are endeavoring to place their seaports in a position to compete successfully with foreign rivals for the possession of sea trading supremacy, with all its prestige and advantages.

One point which is very apt to be overlooked by those whose acquaintance with the technical side of the subject is somewhat limited is that harbour improvement works are not the product of a day or a week. They cannot be called into existence at the precise moment when the necessity for them is clearly recognizable and when their immediate use is absolutely demanded. They necessitate long months and years of careful preparation and execution. They involve much anxious thought and patient labour. They are subject to interruptions and delay at the hand of nature according to her variable moods. The mandate for them therefore must be issued betimes, otherwise their completion will only synchronize with their supersession by standards of a later date and requirements of a more rigorous nature. The creation of accommodation for the ships of ten years hence must be put in hand forthwith, if any effective and reasonably prolonged benefit is to be derived therefrom. Three, four and five years may easily be consumed in the course of constructive operations when they are on any large scale, and by the end of that time it is probable that there will be no necessity whatever to demonstrate the need for the additional works, which, if they are to have a useful existence for any lengthy period, must be based on up-to-date lines with a liberal provision for coming developments.

THE MANUFACTURE AND USE OF HIGH-SPEED STEEL

MAKING THE TOOLS

By O. M. Becker

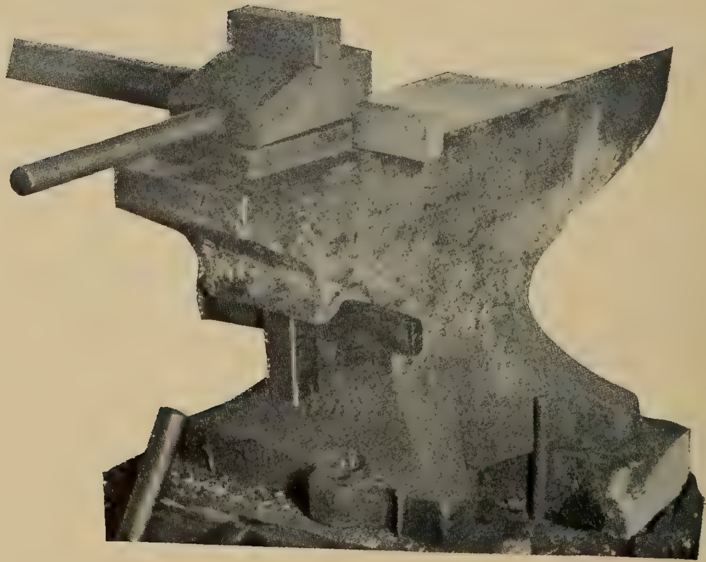
In the August issue of this magazine, Mr. Becker discussed the constitution of the modern high-speed steels and the general methods of manufacture, together with a consideration of questions of hammering, rolling, and annealing. In the present paper the subject is continued by a description of the methods of making the tools, showing the differences between these special alloy steels and the ordinary carbon tool steels, both as regards the manipulation of the metal and the use of the tools themselves.—THE EDITOR.

THE demonstrated utility and all-round superiority of high-speed steel for tools in most lines of metal working, and in other lines also, would lead to the inference that they are used to the largest possible extent. A recent study of machine-shop conditions throughout the United States has shown conclusively that, while they have taken a very large place in productive industry, the new tools are not used to anything like the extent they might be with profit. In a comparatively few shops high-speed steel is largely used; in most to a very moderate extent; while in a great many its use is still quite unknown.

Conservatism, of course, plays a large part in this condition of affairs, while unfortunate and misleading experiences seem to be responsible for the indifferent or negative attitude in many quarters. That there have been unfortunate and misleading experiences is for the most part due to the unintelligent manner in which the new proposition, that of using high-speed tools, is generally attacked. Persuaded in one way or another to buy some high-speed steel, the management of a shop more than likely turns the stock over to the regular tool makers, who are in this case almost sure to be unfamiliar with its properties and the methods of treating it; and more than likely also prejudiced against such new-fangled stuff. Under these circumstances it is not surprising that tool makers so often fail to profit to the largest extent by the directions furnished with the steel. Even when these necessarily brief and incomplete directions are followed as faithfully as possible, the inexperience of the smith makes his efforts more or less experimental, and the results may or may not be satisfactory.

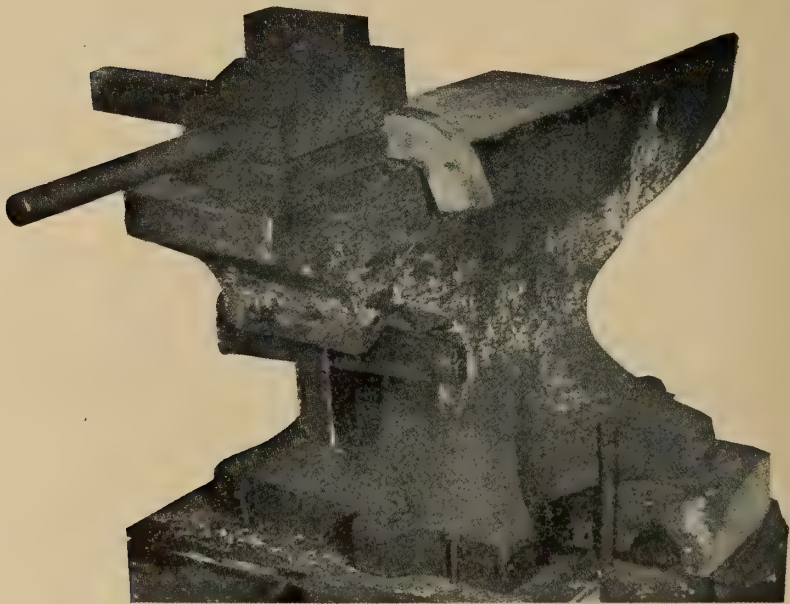
The obvious thing to do for such introductory experiments is to buy tools made to specifications. This also is the proper procedure in small shops using few special tools, even after they have gone into regular use. Makers are quite ready to furnish tools of any pattern to specifications designating precisely the material upon which they are to be used and the machine and other conditions under which they are to be operated. In this way there can be little question of the satisfactory nature of the results.

The making of the common forms of lathe and planer tools is so simple a thing, however, that it can be undertaken in almost any shop having tool-dressing facilities, provided the smith is willing to forget for the time being some of the things he already knows concerning carbon steels and is also prepared to learn a few things which may be quite surprising to him, particularly if he has no previous experience with high-speed steel. His knowledge of colors as a guide to heating and tempering tools will be no guide at all, and will serve only to mislead him.



TOOL CUT OFF FROM BAR AND CLAMPED ON SMITH'S ANVIL READY TO BEND DOWN (OR, AS IT IS TERMED, "TURNED UP")

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)



TOOL BENT DOWN ACROSS EDGE OF THE ANVIL ("TURNED UP")

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)

Whether it be in a large or a small plant, unless the work is in the hands of a trained expert, the first experiences in the making of high-speed tools should be with the simpler forms already indicated. These usually require little in the way of special appliances in order to give fairly satisfactory results. In their making, nevertheless, is involved the same special knowledge as to treatment which is necessary in the case of more complex tools.

Formerly it was a common practice to use high-speed lathe tools in connection with tool holders, merely breaking off from the bar a piece of the desired length, grinding it to the required point, and inserting it in the holder. This is still largely done where the work is light and the speeds not intended to be very high. The unannealed stock was once quite generally used for the purpose. This stock, however, while very hard, has not (in the case of most brands, at any rate) passed through a proper hardening process, having acquired its hardness while cooling under the stresses of the rolls or the blows of the hammers. To insure an even temper and the absence of strains which tend to imperfections, and therefore short service, it is necessary to anneal the tool pieces and then to harden them properly. For this reason, as well as for the greater ease in separating the desired piece from the bar, the annealed stock should be used, thus avoiding the annealing process in the subsequent process of making the tool.

High-speed steel bars which have been so annealed can easily be nicked and broken off. This, however, is not advisable, for the breaking is apt to cause a disarrangement of the structure of the steel near the fracture sufficient to damage the tool at that place. Frequently fine cracks are thus started, which later develop and eventually ruin the tool. It is safer, and when the nose of the tool is to be forged, anyway, it is no additional labor to heat the metal and cut it off hot. In general also it is more convenient to forge tools of this sort before cutting from the bar.

Where many pieces are used, whether of the same or of different lengths, especially if little or no forging is required, it is cheaper to saw the material off to length by a power saw. It is not necessary to saw off each piece at a time, since a large bunch of "tool-holder" stock can be sawed through as if it were a solid bar, if it is clamped tightly and sawed close to the support.

HEEL OF TOOL BEING DRAWN DOWN UNDER STEAM HAMMER TO GIVE SUPPORT TO THE NOSE ALMOST DIRECTLY BENEATH THE CUTTING EDGE

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)

In making tools requiring more or less machining there is an additional advantage in the use of the annealed stock, in that this stock is readily machined; almost if not quite as

easily as carbon steel used for the same purpose. For some kinds of tools this is a matter of considerable importance. Again, the annealed stock is stronger; that is to say, tougher, and tools made from it are therefore better able to resist stresses in the neck or shank than if made of the unannealed material, and on that account are less liable to breakage at those points. The tremendous stresses and strains accompanying the use of these tools make it important to look to this matter. The early complaints against unevenness have almost wholly ceased since makers, mindful of their own interests, as well as of the interests of the users of their steels, have made a practice of sending out annealed bars only, except upon special order.

For forging, any good fire, a common forge fire among the rest, will serve, though, indeed, here, as in other cases, the better results can be expected where the better appliances are used. The first essentials are to secure the required heat and to keep air currents away from the tool while heating. This is accomplished in part by keeping a deep and clean fire. Coke is better than the ordinary smith's soft coal.

Very good results are often obtained with small tools thus heated in an open fire. More satisfactory results may be expected, however, if a fire-brick hood is built over the fire. This serves to prevent the radiation of heat and the circulation of air currents, and is a necessity in heating tools of any size in a common forge fire. It also makes it easier to conform to another prime essential, bringing the heat up gradually and evenly on all sides of the tool so as to penetrate uniformly throughout. This point is very important. Un-

CUTTING ROUGHLY TO PROPER LIP ANGLE

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)

less the mass to be forged is uniformly heated throughout, it will work unevenly, with the result that internal strains are set up which may easily cause a failure of the tool when it is put at work, if not before. Furthermore, if the heating be too rapid there is a liability that the same thing will happen; that is, that internal cracks will be formed which will later ruin the tool.

It does not follow, on the other hand, that the heating must be tediously slow.

If heated too slowly the heat soaks up into the neck or shank, and when hardening takes place this important part of the tool loses part of its natural toughness; a thing to be avoided, as already pointed out. The fire should therefore be clean and well supported by good fuel. Care must be taken withal that the fire be not too keen, or it will not heat through properly. In that case the outside is likely to be white hot and the tool apparently well prepared for hammering, whereas in fact the interior may not be at all ready for working, only the outside being in proper condition. If the interior is not at least hot enough to be bright red, it is not ready for hammering. It is, of course, impossible to know the condition of the interior of a piece of heated steel except by its behaviour under the hammer after removal from the fire, and it is therefore largely a matter of personal judgment based upon experience to determine the proper time during which a particular tool is to be heated. As a general guide it is safe to assume that a piece having a section not larger than one inch, if properly protected as advised above, or if heated in a good coke, oil or gas furnace as hereafter described, will be ready for forging when the exterior has reached a bright yellow. No hammering should be done under any circumstances when the steel is

CUTTING FRONT CORNERS OFF OF THE NOSE SO AS TO APPROXIMATE TO THE PROPER CURVE

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)

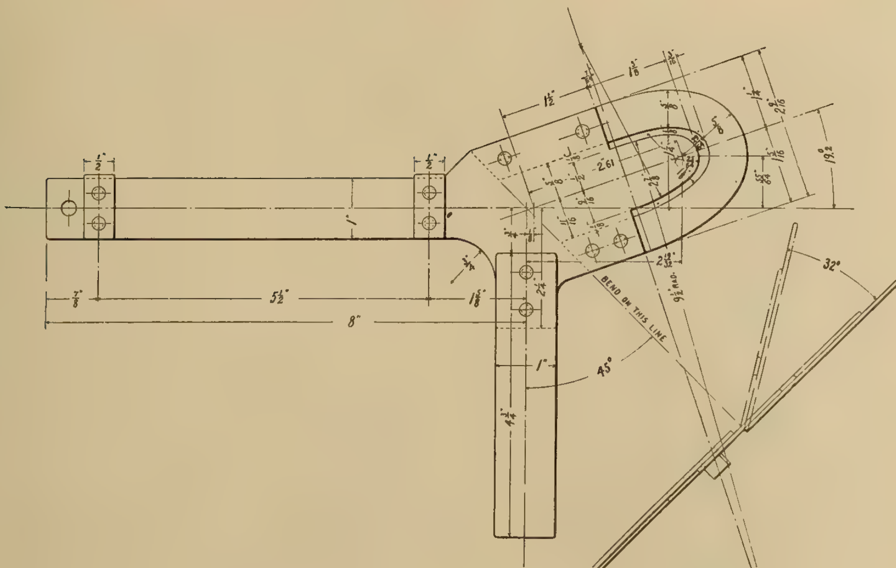
under a bright red, for fine cracks are almost sure to develop if nothing worse occurs. Quite often tools that have been forged at too low a temperature burst while being hammered or machined, and still more often while being hardened. Sometimes the damage does not appear until the tool suddenly fails after being put at work.

It is better to do all forging at an orange or canary yellow, even than at a bright red, though different makes of high-speed steel vary more or less in this respect. The makers usually give explicit directions on this point. The temperature range, therefore, is a hundred or more degrees above 1000 degrees C. With this kind of fire, however, exact temperatures are a matter of no concern, since it is impracticable to measure them under these conditions with any degree of accuracy. Anyway, all that is necessary in the way of temperature regulation, no matter what kind of fire is used for forging, is to keep the heat above a bright red, and the eye is as good a guide as is necessary for that.

TRYING TOOL AGAINST CONE GAUGE TO TEST PROPER ANGLE FOR NOSE

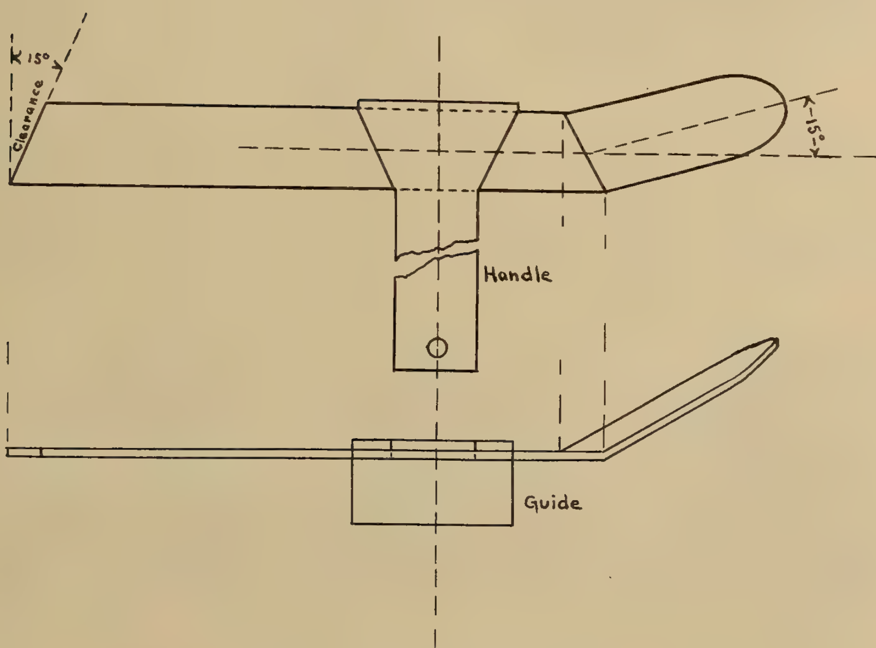
(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)

Although it is possible, as has just been said, to obtain excellent results with a common forge fire when protected by a hood, and even without the hood if sufficient care be taken; it really does not pay to depend upon

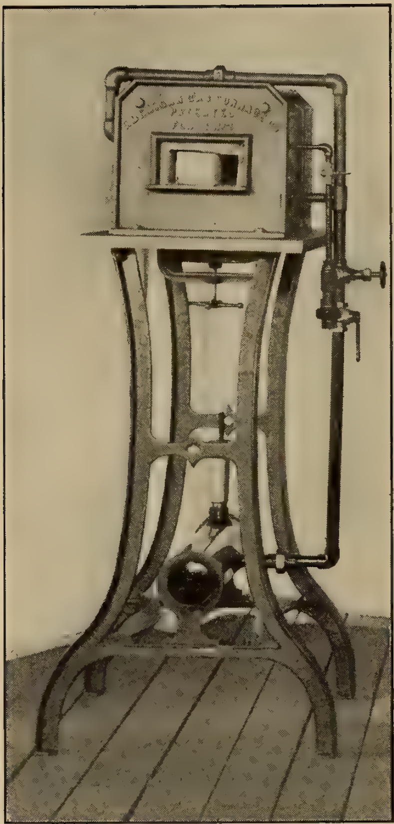


LIMIT GAUGE FOR FORGING THE 1-INCH TAYLOR ROUND-NOSE ROUGHING TOOLS

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)



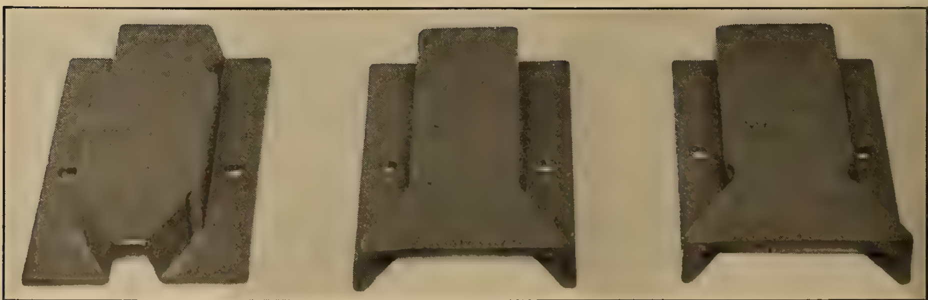
SIMPLE GAUGE FOR STANDARD ROUGHING TOOL



GOOD TYPE OF GAS FORGE. MADE BY THE AMERICAN GAS FURNACE CO., NEW YORK

such crude appliances for turning out tools which shall be uniformly satisfactory in their performances. Especially in a shop where considerable tool smithing is done, a suitably designed furnace is indispensable. A gas forge naturally is the most convenient. The temperature is very easily regulated, and the heating of the tool can be watched from beginning to end. The cost of fuel is greater than with other types of forges, though this is offset by the greater convenience and certainty of results. Oil forges are sometimes used, but are not recommended.

Where gas is not available, or where it is thought too costly a fuel, a coke or anthracite furnace can be used to advantage, serving as well for the hardening heats as for the forging. A good form, easily built and kept in order, is shown opposite. This consists essentially of an iron frame supporting a fire-brick fire chamber. Sheet metal fuel supply chutes are provided at both sides, the fuel thus gradually working down to the center and forming a hollow fire supported by a deep bed of live coals resting on sectional fire-bars at the bottom. Air from the blower is introduced into the ash pit and wind box below the grate. The fuel, in its descent to the fire chamber, is gradually heated and does not prevent the maintenance of a uniform temperature. A constant, even fire can be maintained for a long time practically without attention. The temperature is regulated by the amount of air introduced, and is easily controlled by the cut-off in the supply pipe. Provision is made for shaking or poking down the cinders and ash. As the gases from a coke fire are



A SET OF FORMING BLOCKS TO BE USED IN FORGING LATHE TOOLS, FURNISHED BY GISHOLT MACHINE COMPANY WITH THEIR TOOL GRINDER AND FORM CHART

almost or wholly non-oxidizing, a tool is not injured from this cause even if left in the fire a long time. Another important advantage for this furnace is that the fire is wholly confined, so that there is no waste of fuel or discomfort to the workman.

The proper heat having been obtained, the forging is done in the customary manner, care being always taken that the temperature does not fall below a bright red, as has been already mentioned. It is well to shape the tool as closely to the required design as possible without over-refinement, in order to reduce the amount of grinding, and for this reason gauges for testing the form of the tool should be freely used during the progress of the work. In some cases, in forging the steel to the required shape, it is even desirable to use forms in connection with the anvil. There may be a combination gauge giving all the angles required in the tool, or, less conveniently, there may be a gauge for each. Mr. Taylor describes and illustrates a gauge consisting of a small surface plate with a hole in one corner, into which is fitted a cone, giving the angle made by the heel of the tool with the face of the plate. He also describes and illustrates a limit gauge, indicating the limits within the nose of the tool must be forged. These limits may vary in different shops according to the opportunities for grinding. Where the facilities for automatic or semi-automatic grinding

FORMING A BENT SIDE TOOL

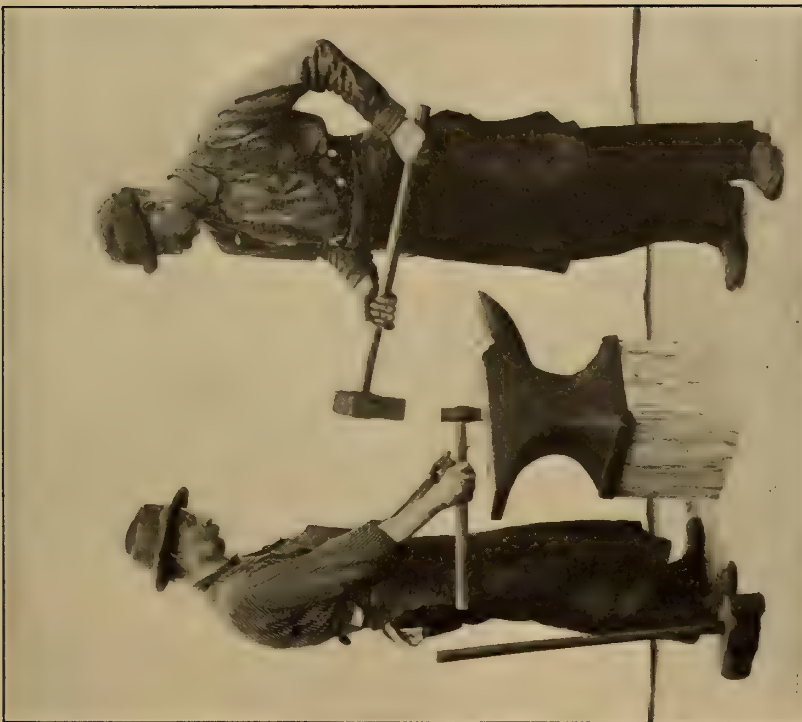
are excellent the forging may be less accurate. Hand grinding, however, is more expensive than forging, and where this is necessary the forging should be quite close to the required dimensions. A simple sheet-metal gauge is found very convenient, and it is necessary to have a set of these, giving all the angles for the several tools to be made, each gauge giving all the angles for the tool for which it is intended.

For testing the form and angles of the Taylor standard tools the limit gauge already mentioned would be used, or perhaps something more simple, such as a piece of sheet metal of suitable thickness to hold its shape permanently and having the exact shape of the top of the tool. At the end opposite the nose is the angle supplementing the angle at the heel of the tool, against which it is placed when testing, the base of the tool and of the gauge both resting on the surface plate.

It might seem superfluous to give special directions to a competent tool smith as to the manner of forging. There are, nevertheless, a few precautions which may profitably be observed in connection with points which are apt to be overlooked except by one of experience in the working of high-speed steel.

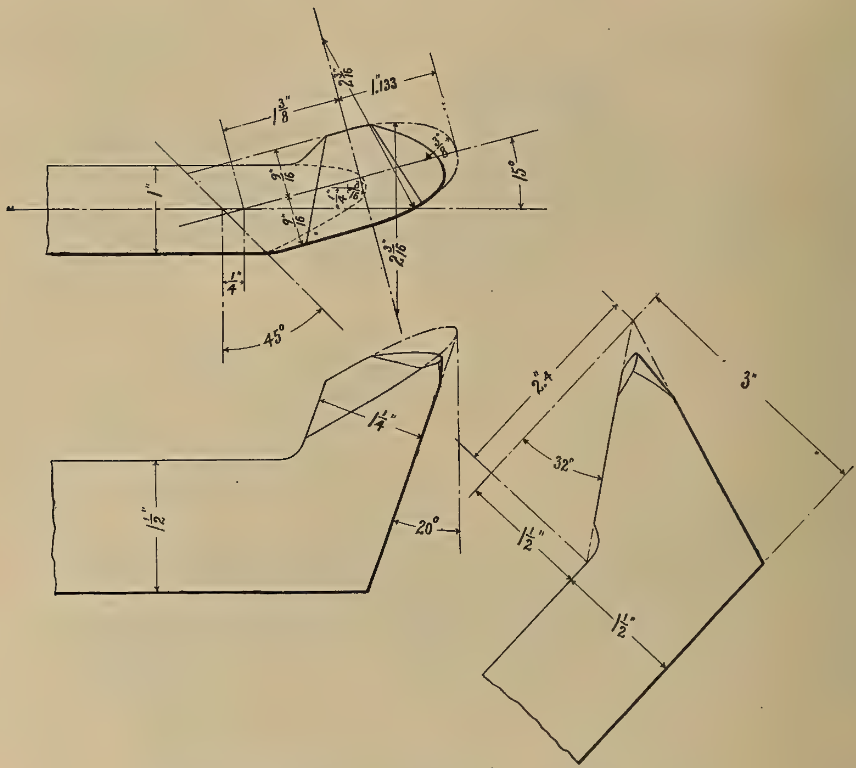
FORMING A SIDE ROUGHING TOOL

First: In heating the tool it is well to watch it carefully, turning it occasionally to insure uniform heating. Fire cracks often result from the uneven heating following the neglect of this point. The heat should not be allowed to soak up into the neck or shank very far, since in that case this part hardens along with the point when it cools down, and destroys the toughness inherent in the



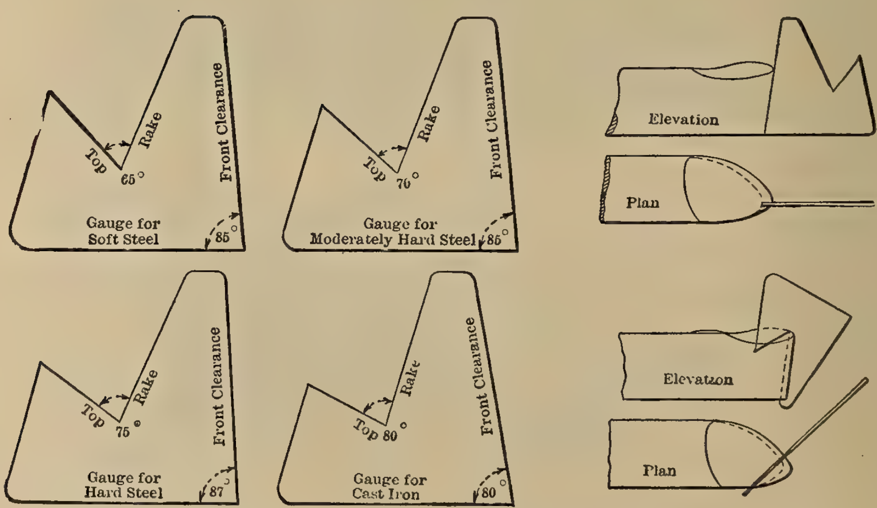
TRIMMING AWAY FOR CLEARANCE, BENT SIDE TOOL

TRIMMING FOR CUTTING FACE OF SIDE ROUGHING TOOL



DETAILED DIMENSION OF 1-INCH ROUND-NOSE ROUGHING TOOL

(From the Art of Cutting Metals, by F. W. Taylor, Trans. A. S. M. E.)



SIMPLE GAUGE USED FOR TESTING ANGLES OF ENGLISH FORM OF BLUNT-NOSE TOOL. DEVISED BY SAMUEL OSBORN & CO., LTD.

SMALL HAMMERS FOR CRUCIBLE STEEL FORGING AND TILTING. THOS. FIRTH & SONS, LTD., SHEFFIELD

tool when in the annealed state.

Second: The forging should be done rapidly, so as to be completed in one heat if possible. Taylor standard tools, with their relatively large amount of work, generally require two, and even three, heats, according to the number of helpers and the use or non-use of a steam hammer. The caution against forging after the temperature has gone below a bright red heat, already given above, will bear repeating here.

Third: The force of the blows should be proportioned to the thickness of the piece being worked. Tools are often damaged by being hammered so lightly that the force of the blows does not penetrate very far into the mass, the interior being scarcely worked at all, and thus stresses are set up which sooner or later result in the formation of cracks.

Fourth: The under side of the tool should be trued up, since it is on this side that it is supported in the tool post or rest. The stresses are so great that the tool needs as perfect a base as possible to rest upon, otherwise there will be vibration when cutting.

Fifth: No nicks or marks should be made on the tool, except at the end opposite the cutting nose. It is customary to mark tools in some way for identification, usually by stamping them with a steel letter or other symbol. Such marks, especially if deep, are almost certain to cause the starting of cracks, which are apt to eventuate in the ruin of the tool. If the mark is put at the end of the tool furthest from those portions subjected to the stresses no harm is likely to result. Even in this case, however, the marks should be no deeper than is necessary to make them legible.

No tool should be forged which can, without prohibitory expense, be machined from stock. This generalization practically limits forging to tools made entirely of high-speed steel for lathes, planers, shapers, and slotting machines. Even these tools, however, can in certain cases be made with the stock and supporting portions of machinery steel, while the cutters are of high-speed steel. In such cases the forging for these is eliminated, as in the case of milling cutters and other formed tools.

RAILWAY BRIDGE FLOORS—OLD AND NEW

By Conrad Gribble, A. M. I. C. E.

SOME account of progress in the design of railway bridges of moderate span during the last eighty years was given in the August issue of this magazine, and special attention was called to the main girders of the bridges described. In the present paper it is intended to point out briefly the development of the floor system in these bridges, treating it as distinct from that of the bridges as a whole.

In designing a floor for a bridge carrying a railway over a road, a river, or a ravine, the problems awaiting solution are quite different from those met in designing the main girders. The floor should be dealt with separately, but it should be considered with as much care as is given to the consideration of the other parts of the bridge. In the actual calculation of stresses in the whole structure, it is usual to begin with the floor system, since until this is designed the loads to be borne by the main girders cannot be exactly computed. In the examination of early designs for railway bridges one cannot but come to the conclusion that more thought and care was given to the main girders than to the flooring, and in many cases the latter is considerably weaker in the face of modern requirements than the girders. One reason for this fact is that old cross-girders appear to have been designed in a rather haphazard way; another is, that while axle loads have become far heavier of late years, the wheels of locomotives are now very closely spaced, and a third is, that special classes of vehicle, formerly unknown, are built now-a-days in order to carry heavy freight, such as minerals, boilers, and machinery, and these put very severe concentrated loads upon the details of the floor systems of under-bridges.

The late Sir Benjamin Baker, in his work on "Long and Short Span Railway Bridges," said that there was (in the early seventies) a tacit understanding among engine builders in this country to limit the load per axle to fifteen tons. Any such understanding that there may have been has long since been abandoned, and the limit of permissible axle load to-day is, generally speaking, 20 tons. Though it is necessary that there be a limit of axle load beyond which locomotive and wagon designers may not go, it is equally important that the closeness of the spacing of the loaded axles be limited, since in many bridges each single cross-girder is required to bear not only one heavy axle, but a large proportion of two or three when the latter are closely spaced. If the cross-girders of all the bridges on a single railway be designed for a fixed axle load of, say, 15 tons, and it afterwards be decided to build a new engine with, say, 20 tons per axle, there may be little increase of stress on the main girders of the bridges on the line, but the stress on every cross-girder is at once increased beyond that for which they were designed, and in such a case the percentage of increase of stress in the cross-girders is far more than the percentage of increase in the main girders.

Thus it is that in many old bridges the flooring is the only part which now requires renewal, and the present margin of safety is, as a rule, less than that in the main girders.

Apart from the question of strength, though this is the most im-

portant consideration, there are other reasons why old bridge floors are a source of trouble to the engineers responsible for their upkeep.

In the case of all bridges over public highways, whether these are town streets or country roads, it is now required that the floors shall be perfectly watertight, so as to prevent the nuisance of dirty water dropping on the road and footpaths, and, further, that they shall be as noiseless as possible under traffic. The latter requirement not being of such importance as the former, is not pressed with as much vigour, but the question of watertightness is one which has continually to be dealt with, sometimes with a great deal of expense. The engineer, moreover, has not only to ensure that the public is not subjected to annoyance from water leaking through his bridge, but he has also to do his utmost to prevent this water from damaging the bridge itself, and it is found that early bridge floors were often so constructed as to give the maximum amount of trouble in both these directions. If the floor of a bridge is dry and unattacked by corrosion, it is a rare occurrence to find the main girders in a bad state, and in nine cases out of ten, if any part of a bridge suffers from rust, it is the floor, the attachments of the floor to the girders, or that part of the girders in contact with the floor.

In the various bridges described in the previous article, nearly all of which are or were on lines now forming part of the North-Eastern Railway system, it was seen that the use of metals superseded the use of timber and masonry to a great extent, and that in the case of metals, wrought iron superseded cast iron, and was itself superseded by steel.

In the floors of these bridges, however, timber was largely employed for a longer time than in the construction of the main portions of the bridge, and in some respects it was admirable. It formed a light and elastic platform, cheap and easily renewed. It was not, however, on the whole, a desirable form of construction, and its employment in this way has almost ceased. Its very lightness and elasticity prevented a close connection with the main girders of iron, and the two materials could not be made into a homogeneous structure. It retained moisture for a long time, and hastened the corrosion of the metal with which it was in contact by holding a film of water in the interstices between itself and the girders. Another and a serious objection to its use is, that it is inflammable, and the floor of a bridge is the part most subject to danger from fire, by reason of hot ashes dropping from the fire-boxes of the engines. This can be guarded against by covering the timber floor with a layer of ballast, but unless the depth of the latter is considerable, and the dead weight put upon the girders therefore great, the vibration of the bridge is apt to expose the timber in places by shaking up the ballast in heaps. When asphalt is used for this purpose instead of ballast it often cracks, owing to the elasticity of the timber beneath, and concrete suffers in the same way. In the case, of course, of bridges in which the ordinary ballasted permanent way is used, the danger of fire does not occur, and this risk is present only in the case of bridges of the type shown in Fig. 1.

This is the flooring of the cast-iron girder bridge over the River Tees at Thornaby, designed by Robert Stephenson, and it is a good example of a large number of bridges in Great Britain. As first constructed, the bridge was without the longitudinal timbers, and the permanent way was attached directly to the cross-bearers, which were 2 feet 6 inches apart (centres). The longitudinals were added soon after the bridge was built to give additional strength by a better distribution of the moving axle loads. The effect of these timber floors was to fail to take full advantage of the width of the

bridge as a steadying factor. In the bridge under consideration, each pair of main girders was connected together by transverse wrought-iron straps passing under the bottom flanges. If diagonal bracing had been introduced, the strength of the bridge in resisting swaying effects would have been largely increased. The timber flooring was not sufficiently rigid in itself nor connected firmly enough to the main girders to withstand the vibration and horizontal deflection caused by loads moving at speed. There is no reason why a horizontal system of sway-bracing with diagonal ties should not be introduced into such a construction, but as a matter of fact it seldom was, and its absence was a more serious thing in a timber floor than in a bridge with continuous plate decking, which is stronger laterally than any sway bracing which would be employed.

In this bridge at Thornaby the drainage question was not very serious, judging by the excellent condition of the girders up to the time they were removed. Though there was a large surface of cast iron in contact with timber and ballast, this metal is so little attacked by corrosion that practically no damage was done during the 60 years the bridge was in existence. Wrought-iron girders would probably have told a different tale, as there was no possibility of cleaning and painting the surface in contact with the flooring. As to the strength of the floor, if designed to-day it would probably be considered on the usual assumptions, strong enough for an axle load of from six to eight tons, because it is usual to neglect the distributing effect of the rails and longitudinal timbers, whereby several cross-girders combine to carry each loaded axle. In actual fact, axle loads of as much as 18 tons were constantly upon the bridge, without any signs of damage to the timber floor; but if such a floor were required to be designed now, the 12-inch square timbers would have to be placed close together throughout, instead of being spaced at 2 feet 6 inches apart. Such solid timber floors have been employed in many cases under ballasted permanent-way, and very strong constructions they are, but their effect on wrought-iron main girders is very bad. Coming to wrought-iron bridges where cross-girders of the same material are used, we find more than one type of construction. Sometimes the whole bridge was decked with iron plates forming a water-tight platform on which the ballast was laid. Sometimes this plate decking was left exposed and the rails were laid on longitudinal timbers bolted to the plates. In some cases no plate decking was laid in, but the cross-girders were covered with timber planks in one or more layers, which in turn carried either ballast or longitudinals. In other cases the longitudinals rested directly upon the cross-girders, and the timber decking was laid between them.

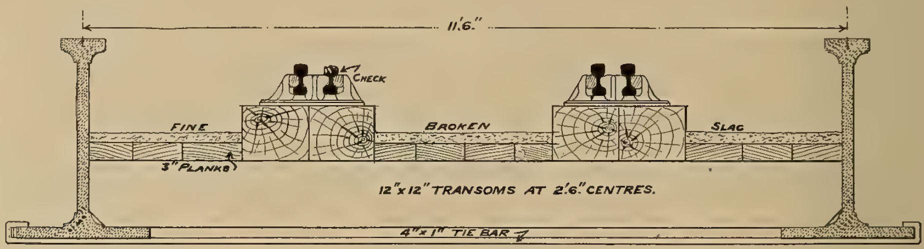


FIG. 1.—OLD TYPE OF TIMBER FLOOR. BRIDGE OVER RIVER TEES AT THORNABY

Such floors are illustrated in Figs. 2 and 3, the first showing a ballast

floor upon decking of old sleepers, the second longitudinal way-beams resting directly upon the cross-girders. The weakness of the cross-girders is very apparent in Fig. 2. This bridge was built in 1852 for the Leeds Northern Railway, and consisted of very strong main girders of "box" type, supporting a very inferior flooring. The attachments of the cross-girders to the main girders strike one at first as quite inadequate. Though the bridge was of double-line width, it never carried more than a single line, which was placed to one side of the bridge so as to put as little bending moment as possible upon the cross-girders. The latter were spaced at 2 feet 6 inches apart (centres) and there was a fair distribution of load over them, due to the sleeper decking and ballast covering. There was no sway bracing of any kind, nor were there any ties connecting the main girders apart from the cross-girders, and fortunately the box girders were stiff enough to prevent the few rivets in the cross-girder connections all working loose. An iron plate deck would no doubt have greatly added to the strength of this bridge, not only by tiering the main girders together and stiffening the whole bridge laterally, but also by providing a top flange to the cross-girders, which were very deficient in flange area. The design seems fairly suitable for an ordinary roadway on which no specially heavy loads are taken, but it is quite inadequate for locomotives, as the flooring is not up to the standard of the main girders. The whole bridge was replaced some years ago by a modern structure.

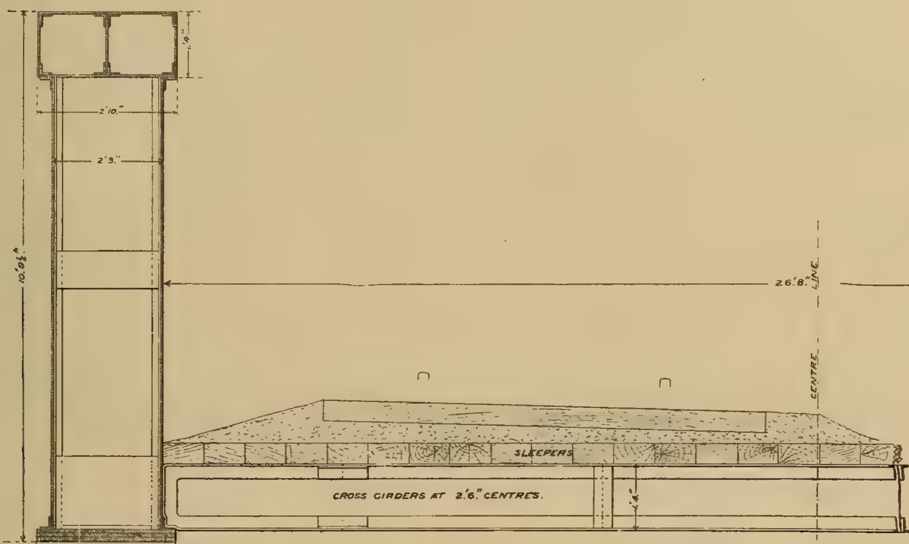


FIG. 2.—BRIDGE OVER THE RIVER SWALE AT MAUNBY, BUILT FOR THE MELMERBY AND NORTHALLERTON BRANCH OF THE LEEDS NORTHERN RAILWAY IN 1852. ENGINEER, THOS. GRAINGER. (REPLACED WITH A STEEL BRIDGE, 1899, W. J. CUDWORTH, ENGINEER.) WROUGHT IRON BOX GIRDERS 155 FEET LONG, 10 FEET 9 INCHES DEEP

In Fig. 3 we have a floor made about ten years later, which is, in some respects, stronger than that in Fig. 2, but has many noticeable faults. In this case the cross-girders are spaced 5 feet apart (centres), and the rails are carried on longitudinal timbers. These are barely strong enough to carry the present axle loads over a clear span of 4 feet, and certainly not so if a slightly

defective or loose rail-joint occurs between two cross-girders near a joint in the timbers. They were, however, strong enough when they were designed, as the axle loads did not exceed 15 tons, and there is no reason why deeper timbers or timbers strengthened by steel longitudinals should not be added to bring the strength up to the modern standard. As to the cross-girders themselves, they are very weak when loaded simultaneously on both sides. The attachments to the main girders are by suspension bolts, an undesirable feature unless specially forged bolts are used. The deflection of the cross-girders will also put a great strain on the two bolts on the inside of the girder, whereas if the cross-girders were stiff and strong the load would be more uniformly distributed over the six bolts forming the connection. To counteract this deflection to a certain extent, the stiffness of the main girders comes into play, and fortunately in this case they were strong and well provided with stiffness. In both these floors (Figs. 2 and 3), owing to the nature of the design, the upper surfaces of the cross-girders are very liable to corrosion, owing to their being in contact with the timber decking, which is not by any means watertight, and no attempt seems to have been made to devise any means of protecting the most vulnerable part of the structures against deterioration. When we turn from these floors to modern ones we find that cross-girders are now made immensely stronger to cope with the heavier axle loads, and longitudinals of steel are, as a rule, laid in between them. The tendency is to space them farther apart, and all the connections of longitudinals and cross-girders are far stronger. Whereas old girders can be used again to a great extent by reducing their length and employing them in shorter spans or by using them for single-line bridges instead of double line ones, cross-girders are always useless when once removed, as they are far too weak and generally very corroded. The riveting is often almost ludicrously inadequate.

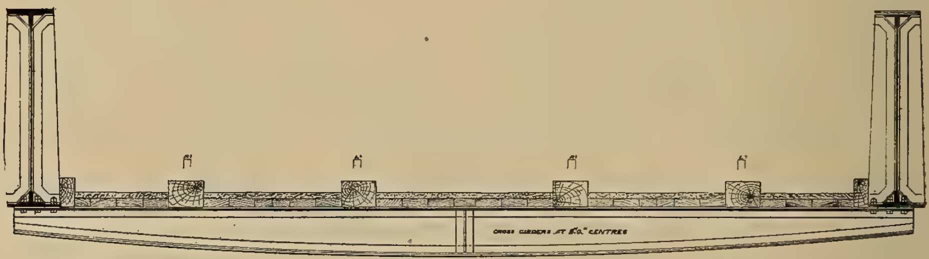


FIG. 3.—OLD TYPE OF FLOOR. SUSPENDED CROSS GIRDERS, TIMBER DECKING AND WAY BEAMS

As a general statement, the span of the bridge does not very much affect the design of the floor system, and it is possible to adopt a uniform and standard type of floor which can be applied with small variation to bridges of widely differing spans and types. In the case of lattice girders, the spacing of the cross-girders and the panel length of the girders are mutually dependent, but in plate girders, and in lattice girders of several systems of intersecting bracing, the spacing of the cross-girders can be anything desired without affecting the main features of the design of the bridge. It is, however, impossible to lay down general rules for the economical spacing of cross-girders or to design one standard bridge floor for all cases. It is true that the load per cross-girder does not increase directly

as the spacing until the latter is very great, and at small spacings a cross-girder strong enough for one spacing is practically strong enough for double that spacing. The obvious deduction from this is that wide spacings are more economical than narrow ones, and this is true within limits, that is, until the longitudinals become very heavy, owing to their length, as the weight of longitudinal girders under ordinary moving loads increases as the square of their span, roughly speaking. The available depth of construction affects the design of the flooring as much as anything, and when this is very small the cross-girders must be closely spaced. For bridges up to 100 feet span, the economical spacing of cross-girders for ordinary conditions is about 8 to 10 feet; above this span it increases to at least 15 feet at, say, 200 to 250 feet span, and in the case of bridges of 300 feet span and over, it becomes a far less important matter, since the total weight of the flooring increases directly as the span becomes small, compared with that of the main girders increasing as the square of the span.

Bridge floors can be broadly divided into two classes; namely, those in which the permanent way is of the ordinary type of sleepers resting on ballast, called "free floors," and those in which the rails are carried over the bridge on longitudinal timbers, called way-beams, attached directly to the steelwork of the bridge, called "tied floors." There are certain conditions which almost preclude the use of way-beams, and others which render a ballasted road out of the question. Way-beams are used in long spans, bridges not situated upon a curve, where lightness is an object; ballasted floors are used in short spans, curved situations, where the superelevation of the rails means awkward cutting of timber if way-beams are used. In steel bridges it is, of course, desirable to have a single type of permanent way uniform with the standard on the railway, but the great weight of the ballast renders it too costly to lay such a road over a bridge of great span. In a span of 300 feet the extra cost of steelwork to support a double line of track on a ballast formation instead of on timbers would be at least a thousand pounds. In long viaducts, consisting of short spans, the extra cost is much less and might easily be more than balanced by the cost of renewing way-beams. The drainage question is most important, and if a ballasted road is used it does not much matter whether the bridge is over a public road or a ravine or river, since the object is to keep the water from the steel. This being done it is easy to keep it off the road beneath. The plate decking carrying the ballast should be protected from moisture by a layer of asphalt bitumen sheeting or concrete. Asphalt or bitumen sheeting in such a situation must be protected against injury from the crowbars of plate-layers by a layer of some material such as old bricks, old sleepers, or timber planks; thin creosoted boards will do where the construction room is limited. The webs of the main girders must also be protected from contact with ballast, and this can be done by a filling of concrete or by a vertical ballast plate along the edge of the girders secured by cleats to the stiffeners or web members of lattice girders.

The illustration (Fig. 4) shows a ballasted floor designed for a bridge over a public road in the city of Hull. Here the bridge had, of course, to be quite watertight and as noiseless as possible. The filling of concrete at the sides should not terminate in a vertical face flush with the edge of the girders so that the gusset stiffeners cut it into short pieces, as when this is done there is a great tendency for it to break away from the girder webs, making matters far worse than if no concrete had been used at all. The asphalt is carried over the concrete and finished in a small groove formed against the web

of the girder, which prevents any possibility of a crack forming there. This method of finishing off the side of the bridge with concrete is rather in the nature of an experiment, though such constructions are common in ordinary highway bridges. It remains to be seen whether the concrete will adhere to the girders in spite of the vibration and shock of the rolling loads. This bridge carries five lines of way with six girders, being an extension of what is commonly called the "three-girder heavy and the weight of the main girders is thus more than where a lighter type of floor can be used. As the span increases, this extra cost becomes greater, but the absence of the cost of maintaining and renewing timber way-beams can be set off against the extra cost of the ballasted construction. The depth of construction is also greater than the minimum possible with a "tied floor."

In comparison with this floor is shown in Fig. 5 a way-beam construction of a much lighter character.

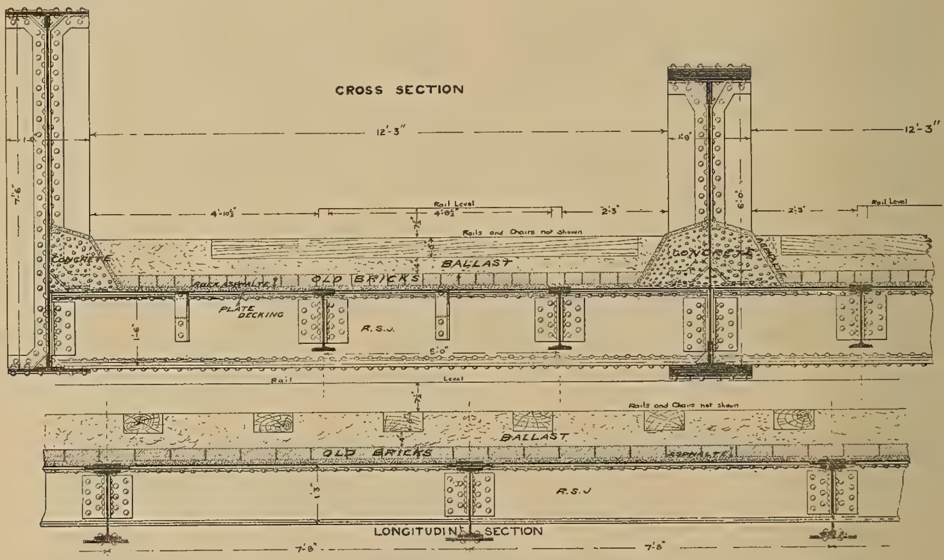


FIG. 4.—TYPE OF WATER-TIGHT FLOOR FOR BRIDGE WITH BALLASTED ROAD. (STONEFERRY RD. HULL). W. J. CUDWORTH, ENGINEER, 1908

type." The same construction with, of course, much heavier cross-girders would be used for a "two-girder type." In such a floor as this a great deal of field riveting is necessary, as the whole of the decking plates have to be riveted across girders, longitudinals and main girders at the site. In building an entirely new bridge this is not such a disadvantage as in the case of renewing an existing structure, where traffic must be interfered with as little as possible, and consequently speed of erection is the first consideration. The floor is Not only is the weight of steelwork in the whole bridge less, but there is far less field riveting necessary, as all the decking plates are riveted to the longitudinals in the bridge yard; the only field riveting is in the connections of the members forming the floor system. The timbers are carried in longitudinal troughs, in which all the interstices are filled with asphalt or pitch; leaving only the upper surface of the timbers exposed to the weather. If well seasoned and creosoted timbers are used, their life in these circumstances is a long one,

and the annual charges for maintenance and renewal are small. In this particular floor there was no need for watertightness, and the decking is made of strips laid with 1 inch spaces between them. The whole of the steelwork, with the exception of the insides of the troughs, which are perfectly protected from moisture or atmosphere, is perfectly open to light and free circulation of air, and inspection of its condition can be properly made from time to time. Scraping and painting is also facilitated, so that, whereas the open character of the construction causes it to be rapidly dried after rain and therefore reduces risk of corrosion, its accessibility allows of the maximum quality of cleaning and painting work being ensured when it is required. If such a bridge is over a roadway, strip-decking is of course not permitted, though, as a matter of fact, the rainwater passing through the open deck and dropping off is not particularly dirty. The decking will, however, be of continuous plate, and it must be carried through to the webs of the main girders instead of being stopped at the edge of the girders, unless some other arrangement is made to prevent water coming through and dropping off the inside edge of the lower flange. The weights of these two floors, shown in Figs. 4 and 5, complete with permanent way, including everything but the main girders, are about 155 pounds and 55 pounds per square foot, respectively, and the weights of steelwork are about 47 pounds and 41 pounds per square foot, respectively. The total cost per square foot for the flooring, including everything but the rails and chairs, is about 8s. 6d., 7s., respectively, for the single-line floor (and about 12s. and 10s. for a double-line floor), showing an advantage on the side of the "tied" floor in every respect. These figures include cost of erection in ordinary circumstances, and are fairly approximate estimates at current prices.

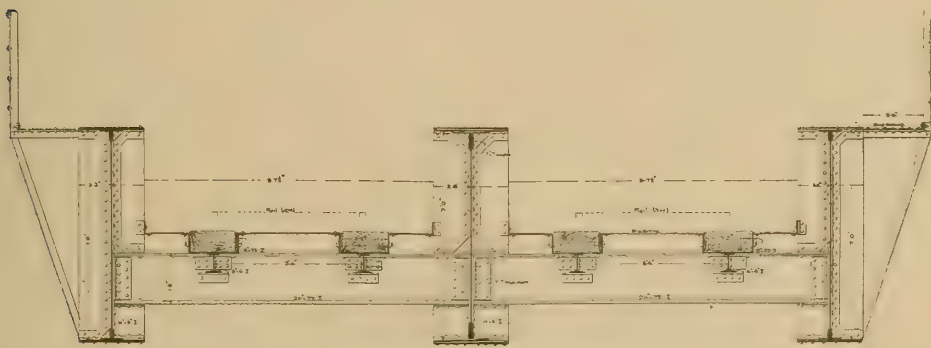


FIG. 5.—RENEWAL OF STEPHENSON'S BRIDGE OVER RIVER TEES AT THORNABY

Steel plate girders 90 feet long, 7 feet deep. Cross girders and rail-bearers of rolled beams and zeds. Renewal carried out, 1906-7. Three spans 90 feet, two spans 30 feet. W. J. Cudworth, engineer.

In both these examples, rolled sections are used as much as possible for several reasons. First, they minimize riveting, both in the field and in the shop; second, they give a better surface for scraping and painting, and third, they are suitable and adaptable for the requirements of a bridge floor. Ample riveting is used in all the cleat connections and is more than is theoretically required, as this is the weak point of many early bridges, and one to be especially avoided, since the increase of riveting only slightly increases the cost, but

greatly improves the construction. In the "tied" floor (Fig. 5) the upper part of the longitudinals is formed of a couple of Z-bars which are continuous throughout the bridge, and the decking holds these in position laterally. The lower part, which is either a single I-beam or a couple of channels, is fitted between the cross-girders and connected to the upper portion by transverse strips or continuous plates, forming a bed for the timbers.

Another and different type of floor commonly used is constructed of various kinds of arched or trough flooring, some of which are patented. It is claimed that these form a very light construction, but it largely depends on the assumptions made in the calculations for the safe loads upon them whether the construction turns out a light one or not. It appears to be a customary thing to assume that the live load is, like the dead load, uniformly distributed over the area of the troughing, but if this is done a very large increase must be made to the actual loads to obtain the true equivalently distributed load on each unit of troughing. It is not correct to design a floor for a railway bridge as if it were a warehouse or granary floor subjected to a uniform static load. When the troughs are laid transversely between the main girders, either on the lower or the upper flange, it is necessary to decide how many trough units may be assumed to support a loaded axle, and in what proportions the load is distributed over them. In making these assumptions one should allow a good margin of safety and not overestimate the distributing power of the rail and ballast, but it is not easy to obtain good and reliable data from experiments. When the units are of a width of from 2 feet to 3 feet, as is usually the case, it seems hardly correct to assume that three such units combine to carry a single heavy axle unless there is a considerable depth of concrete and ballast above them. It appears that such assumptions as these are common, and if so, it accounts for the claim of lightness and cheapness made on behalf of trough flooring. The objections to its use consist mainly of the difficulty of making a good connection with the main girders, and of the difficulty of securing good drainage. The first is an almost insuperable one, and the second can be overcome only by filling the troughs with concrete raised sufficiently above their upper surface to give a thickness which will not crack and let in the water. This is a heavy construction, and therefore costly, but unless it is done it is necessary to drain each trough separately and to connect them by gutters and spouting to make the bridge "drop-dry." In special circumstances where construction depth is very limited, one occasionally sees trough floors with the sleepers laid in the bottoms of the troughs so that the rails just clear their upper surfaces. Of all constructions this is perhaps the most objectionable, and it is the last resource of a bridge engineer, as it is noisy, causing great vibration, and is very dirty in the engineering sense of the word, since none of the matter and moisture collecting in the exposed troughs can be removed at all.

A massive construction where there is ample construction depth is shown in Figs. 7 and 8. Jack arches of brickwork or concrete, either longitudinal or transverse, form an extremely solid and permanent construction, but their great weight and cost preclude their use, except in bridges of small or moderate span. They must be built with great care, to prevent any possibility of moisture percolating between the brickwork and the steelwork. If the arches are formed entirely of good concrete this danger can be avoided. When longitudinal main girders and arching can be employed, as in Fig. 7, the construction, although heavy, is not expensive, as the absence of any cross-girder and

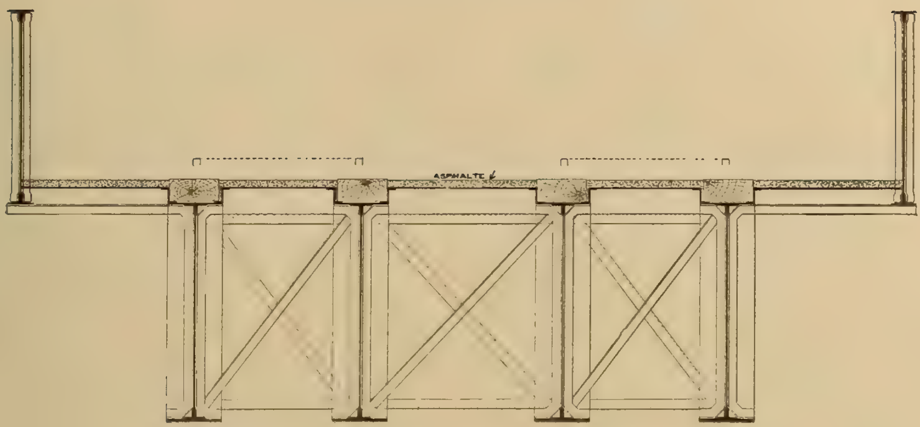


FIG. 6.—"DECK" BRIDGE, WAY BEAMS AND PLATE FLOOR, FOUR MAIN GIRDERS

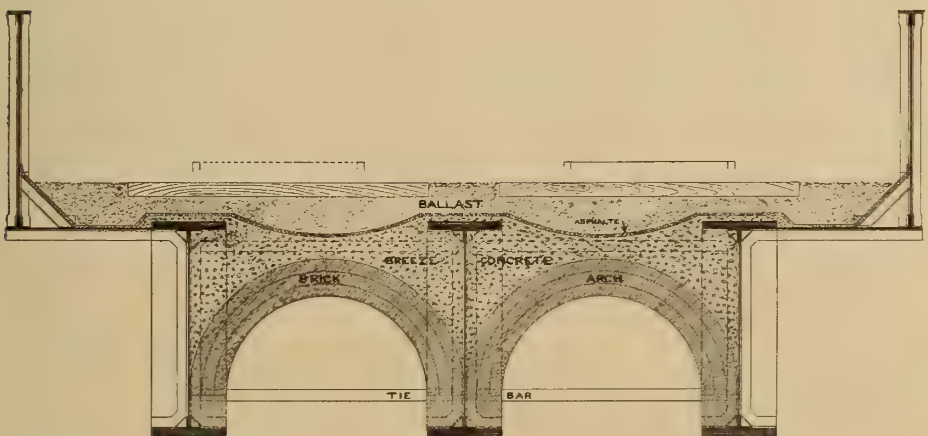


FIG. 7.—DECK BRIDGE. LONGITUDINAL ARCHES, THREE MAIN GIRDERS, DOUBLE LINE

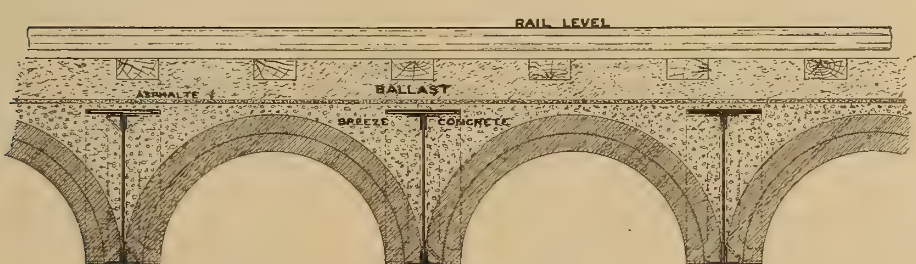


FIG. 8.—BRICK JACK ARCHES BETWEEN CROSS GIRDERS. (MAIN GIRDERS NOT SHOWN)

rail-bearer details balances the extra weight of steel in the main girders, and the cost of the arching in bridges up to, say, 60 feet span. The cost of this construction is not more than that of the lightest steelwork construction which can be made embodying cross-girders, and is also hardly less than the four-girder system shown immediately above it for bridges of this span. Where, however, the arches are transverse, between cross-girders, the cost is far more, and there is little to recommend this construction except the great amount of protection afforded to the steelwork.

If possible the steelwork should be entirely encased in concrete as in Fig. 8, but it is open to the advocates of reinforced concrete to criticise such a construction on the ground of false economy, owing to the strength of the concrete not being utilized, and the steel not being used to the best advantage.

In conclusion, it is useful to notice and to avoid the faults of early constructions when designing a modern bridge floor, and the great points to be aimed at are to attain rigidity and stiffness and to avoid any possibility of corrosion by moisture. Personal opinion often differs as to the desirability or otherwise of a way-beam or "tied" floor as compared with a ballasted or "free" floor. The life of way-beams by proper precautions can be made longer than that of ordinary sleepers in ballast, but they are of course far more costly.

An open-strip deck is very cheap and convenient where the bridge need not be watertight, and the use of rolled sectional steel instead of built-up sections tends to economy and facility of cleaning and painting. It is worth noting that in ballasted bridges, ample camber may be given to the main girders to improve its appearance, and in no way cause trouble or much extra weight of ballast. Though there is a greater depth of ballast at the ends than at the centre of the span there is little increase of bending moment. In the case of way-beam floors, however, the main girders should not be given more camber than is absolutely necessary, as it causes great expense in cutting and packing the timbers to a level surface.

A practice commonly employed in old bridges was to incase the ends of both main and cross-girders, where they rest on the abutments, in brickwork, concrete or masonry, in such a way that they were not protected from corrosion, but only from all inspection and maintenance. Pilasters are a great improvement to the appearance of girder bridges, but they should be a sufficient distance from the steelwork to allow of free circulation of air. There is no reason to encase the ends of cross-girders on a skew abutment, and it is curious to see cases where elaborate expansion bearings have been provided for the main girders while the cross-girders are rigidly held at their ends. In such cases either the roller bearing is useless or else "something has got to give." If a wall of concrete or brickwork be built on the abutment behind the ends of cross-girders and main girders, all the ballast is kept away from the steelwork, which is everywhere open to inspection. In short, all steelwork should either be completely encased in an impervious material or else it should be absolutely open and accessible for inspection, and it should not, if possible, be in direct contact with timber, brickwork, masonry or ballast.

THE RELIABILITY OF THE PRODUCER GAS PLANT

By Godfrey M. S. Tait

IN the October issue of CASSIER'S MAGAZINE there appeared a paper by Mr. Thomas L. White, discussing the reliability or unreliability of the gas-producer plant for power generation, and, in view of the results and deductions there given, the writer feels that some protest should be made, lest a mistaken impression of the real value of the gas-power plant be created.

In the first place, the small size of the producer tested by Mr. White should be considered, especially as a reliable equipment from which to determine results upon which opinions are to be based. A producer of 15 horse-power capacity is 50 per cent. smaller than any which the writer has ever encountered, and is very much smaller than it is practicable from an economical standpoint, since the labour item preponderates to such an extent over the fuel cost as to render the latter of secondary importance.

Apart from this feature, however, it appears that the tests on the first day had to be interrupted, in order to adjust the ignition point, a matter which should have been attended to before starting the trials, since such a shutdown must make the temperature too low to permit proper generation of gas for test purposes.

The troubles mentioned in Mr. White's article are familiar to those who have had practical experience in gas-power development, and may be summed up briefly as follows:

1. Improper adjustment of the gas engine;

2. Lack of knowledge as to the necessary temperature for the production of gas, and consequent mishandling of the fuel bed;

3. Poor design of producer, involving inadequate means for removing ash, and insufficient number of poke holes—probably badly placed.

In comparison with the run referred to by Mr. White, the reader may be referred to the article by Mr. W. Y. Lewis in the issue of this magazine for July last, containing accounts of really reliable producer-gas tests. In the tests reported by Mr. Lewis the plants were required to be operated twenty-four hours a day, six days a week, under varying loads, no shutdowns being required for any cause, and ignition troubles being unknown; and in them the fuel consumption ranged from 0.7 pound of coal at full load to 1.25 pounds when the engine was running light.

In regard to the "skilled supervision" under which the producer described by Mr. White was reported to have been operated, this seems open to question in connection with the statements that the engine was started with an incorrect ignition point, that the valves had to be changed, that the producer clinkered up a good deal, and that much coal escaped unburned from the producer. These facts seem to point very plainly to some of the reasons why unsatisfactory results are sometimes obtained with gas-producer plants, and hardly indicate a very high degree of skill in the supervision.

Mr. White also mentions that "the motor suddenly refuses to carry the load. What is the reason?"

The reason is very obvious: no gas! This is the same kind of a reason which might be expected to cause a steam engine to stop if the man in charge of the boiler should forget to

look at the steam gauge and allow the pressure to fall. Such shutdowns are inexcusable in any well-managed plant, in which the use of a simple pilot light would give the operator an indicator which he could watch and keep himself informed as to the quality of gas being made.

In regard to the difficulty of obtaining an engineer who thoroughly understands his business for the operation of a 30 horse-power gas plant, this brings up one of the most important points in connection with gas-power difficulties. The owner of a small gas plant is unwilling to pay sufficient wages to secure the services of a practical gas-engineer, and places his equipment in the hands of ignorant labourers, or often of newly-arrived foreigners, at the lowest possible wages, and hence trouble is to be expected. The owner of a plant of 100 horse-power capacity or more is justified in paying sufficient wages to secure a competent engineer, who is capable of attending to both gas engine and producer; and under such circumstances he has absolutely no trouble with the equipment. This is the real reason why the gas-power system is not practicable in small sizes, the labour item so far exceeding in cost the item of fuel that the high fuel-economy is almost immaterial. In practice, 50 horse-power is about the smallest plant that it is advisable to install, since anything lower than this precludes the employment of an intelligent operator, because his wages would be out of proportion to the other power costs.

When the results of long experience are taken into account, it has now become practicable to install gas-producer plants which operate with all the reliability of the steam plants which they supersede, and in which the fuel economy is sufficient to warrant the removal of all the steam machinery and its replacement with new gas-power machinery, even at a higher initial cost than that of the equipment which it displaces.

Current Topics

THE important paper by Dr. Bayles in this issue brings up what appears to be an entirely novel feature in connection with the use of flying machines in modern warfare. There has been much skepticism as to the possibility of a dirigible or an aeroplane dropping explosives with sufficient accuracy to enable definite results to be obtained; but the prospect of a machine hovering in the air with a dynamite bomb dangling from it at the end of a few thousand feet of piano wire is a contingency which, we believe, has not hitherto been considered. Such a combination passing over a city or a fortress could hardly fail to do immense damage, and, in the case of certain American cities, the tall buildings would prove easier marks for entanglement with the bomb than those of less aspiring altitude.

The continued development of mechanical methods of warfare has sometimes been cited as leading to greater horrors and destruction, but an examination of the results of mechanical ingenuity in other directions will show that for nearly all operations the number of men engaged has been reduced to a small fraction of that formerly required. This is true in present naval warfare, and has been a matter of interested comment that in the Russo-Japanese war the long-drawn-out and bloody land engagements were nearly all of them indecisive, although the loss of life was enormous; while the single naval battle of the Sea of Japan, conducted between fighting machines, involving comparatively few men with a proportionately smaller mortality, was practically decisive.

In a modern rolling mill the extensive use of mechanical and electrical appliances is a matter of comment by all who can remember the former crowded condition which such establishments formerly presented. To-day a few men, perched in the pulpits of traveling cranes, or ensconced in protected niches among the machinery, control all the movements of the powerful and efficient equipment, and are able to accomplish work in magnitude and volume far beyond the capacity of multitudinous human effort. In like manner, the application of machinery to warfare will result in the exposure of a far smaller number of men to danger than is now the case, and cause the decisiveness

of engagements to be so enormously increased as either to render war obsolete or to become exceedingly brief.

The present floating fortresses known as battleships, costing from one to five hundred times that of the flying machines by which they may be demolished, and carrying several hundred times the number of men in any specific case, may have reached their present development just in time to be rendered altogether obsolete beneath destructive appliances capable of operating in three dimensions instead of two.

War is costly in any case, both as regards money and men; but when millions may be replaced by thousands, so far as the former is concerned, and thousands by individuals in the case of the latter, the cost may become so reduced as to bring it wholly within the scope of mere policing by the nations, relieving the budgets of the greater part of the financial burden, and releasing for civil life hundreds of thousands of men now withdrawn from useful occupations to fill the ranks of the armies of the world.

Viewed in this light the entrance of the flying machine into international warfare need not be considered as an addition to the horrors of war, but rather as a method of concentration of the necessary police power into such a form as shall render conflict less probable, while inflicting a far smaller burden of cost upon the world.

THE question of the training of competent workmen is always open for discussion.. Years ago, when the apprenticeship system was in full swing, there was abundant criticism of the results which it produced, and methods which are now looked upon as parts of the good old times had almost as much fault found with them as some of the present ideas now receive.

To-day the apprenticeship system is practically dead, although it does not seem to know it, and hence it is remaining above ground longer than it ought. By just what it is to be replaced may not be entirely determined, but that is no reason why the obsolete method should not be decently buried and presently forgotten.

Modern shop methods are not conducted in such a manner as to permit an apprentice to learn much by the old system of plugging along and rubbing it in by hard knocks and main strength during the passage of seven years. Indeed, the modern shop keeps the journeyman himself hustling to hold his job, and the functional foreman or "speed boss," with his stop-watch and his instruction card, makes the old-time workman realize that he is never to cease learning.

Mr. R. T. Crane, himself a practical workman and a large employer of labour, does not believe that technical education and trade schools will solve the labour problem, and in this many will agree with him. Mr. Andrew Carnegie, on the other hand, who has been through much the same experience as Mr. Crane, and who has been a still larger employer of labour, believes in technical education, at least within certain limitations, and has so expressed himself more than once.

Mr. Carnegie, at least, realizes the existing state of affairs when he states that the apprenticeship system is a thing of the past, and that a substitute for it must be found. Those who are conscientiously in search of a substitute must take into account the changed conditions under which machine-shop work is done. Modern tools perform automatically much of the work formerly left to the judgment of the mechanic. Limit gauges leave him no discretion as to the dimensions of his product. Speeds and feeds are determined for him, frequently by technical graduates who themselves might perhaps not be able to perform the work, but who, by reason of their scientific training, are

able to show the mechanic how to increase his output for his employer and his wages for himself.

The tendency to hark back to the "good old times" and the "good old ways" is inevitable during transition periods such as the present; but it is only a passing phase, and cannot be a present force any more than a protest against "modernism" can turn the hands of the clock of the world backward. The employer and the workman who do not recognize the truth which surrounds them must inevitably fall to the rear in the course of this irresistible forward movement, displaced by those who, instead of deploring the vanished past, endeavor to meet the inexorable conditions of the ever-facing present.

THE motor omnibus is passing through that phase through which so many things have had to pass in the process of evolution from humbler beginnings. It drops filthy grease wherever it runs, which shows either that it is badly designed in its machinery or that the designer had not the sense to fit oil-catching traps to prevent what he ought surely to have suspected would happen.

In other details there is weakness and want of appreciation of the needs of mechanism. The drivers are careless or unskilled, and allow a surplus of lubricating oil to enter the cylinders, where it is distilled to an offensive fume. An entirely unnecessary degree of noise is produced. We say unnecessary, because here and there a vehicle appears which makes practically no noise. Though unprovided with an animal in front to push away people who would fall beneath the wheels, we have yet to see the motor 'bus whose designer has had the necessary brains and intelligence to guard the leading wheels so as to push aside a fallen person, who, as it is, must inevitably be fatally crushed. To abolish horses from our streets is greatly to be desired. The horse is a filthy thing to be allowed loose in the streets—worse than even a fume-making omnibus; but what we do object to is, that the faults and noise and dangers of the motor omnibus are not those of a type that are unavoidable. Were they so we should be inclined to groan, but to say nothing. But they are preventable. They arise from sheer carelessness and from mere inhumanity. Most of the motor omnibuses are said to be designed in Germany, where there is no sympathy for the man who is run over, and both law and custom favour the vehicle which does the running over, presumably because officials ride and the general public gets run over. These foreign designs are bad and insufficient, and we would advise our omnibus companies to seek to make improvements before public feeling is too much irritated and ill-considered legislation is carried out. The mechanical vehicle is bound to succeed, but this is no reason why a needless disregard should be practiced as to the nuisances which are the result of a mistaken parsimony. Motor-vehicle machinery is too much of the order of the Art and Science Department of twenty years ago. Is there a shaft to be carried? Then here is a plate with a hole in it. Is a brake required? Send the draughtsman to look at the brake gear of that one-horse 'bus, and so on; all of which may be summed up in one word, insufficiency. But better things are coming along, and, it is to be hoped, better dividends will come along to long-suffering shareholders.

JESSE MERRICK SMITH

President American Society of Mechanical Engineers

IT has long been the custom of this magazine to publish each year the portrait of the new president of the American Society of Mechanical Engineers, and it is our privilege this month to give a biographical sketch of Mr. Jesse Merrick Smith, who has been chosen as president of the society for 1908-1909.

Mr. Smith was born in Newark, Ohio, in 1848, and removed to Detroit, Michigan, in 1862. His education was received both in the United States and in Europe, including three years at the Rensselaer Polytechnic Institute at Troy, followed by a year's travel in Europe, after which he attended the *Ecole Centrale des Arts et Manufactures,* in Paris, for three years, where he received the degree of Mechanical Engineer in 1872. He then traveled in France, Germany and Belgium, visiting various manufacturing plants, besides attending lectures at the Polytechnic Institute at Berlin; and also spent three months' travel among the iron and machine works of England.

In 1873 he began the practice of engineering in the United States, designing and superintending the erection of blast furnaces for smelting iron from native ores with bituminous coal in the Hocking Valley, Ohio.

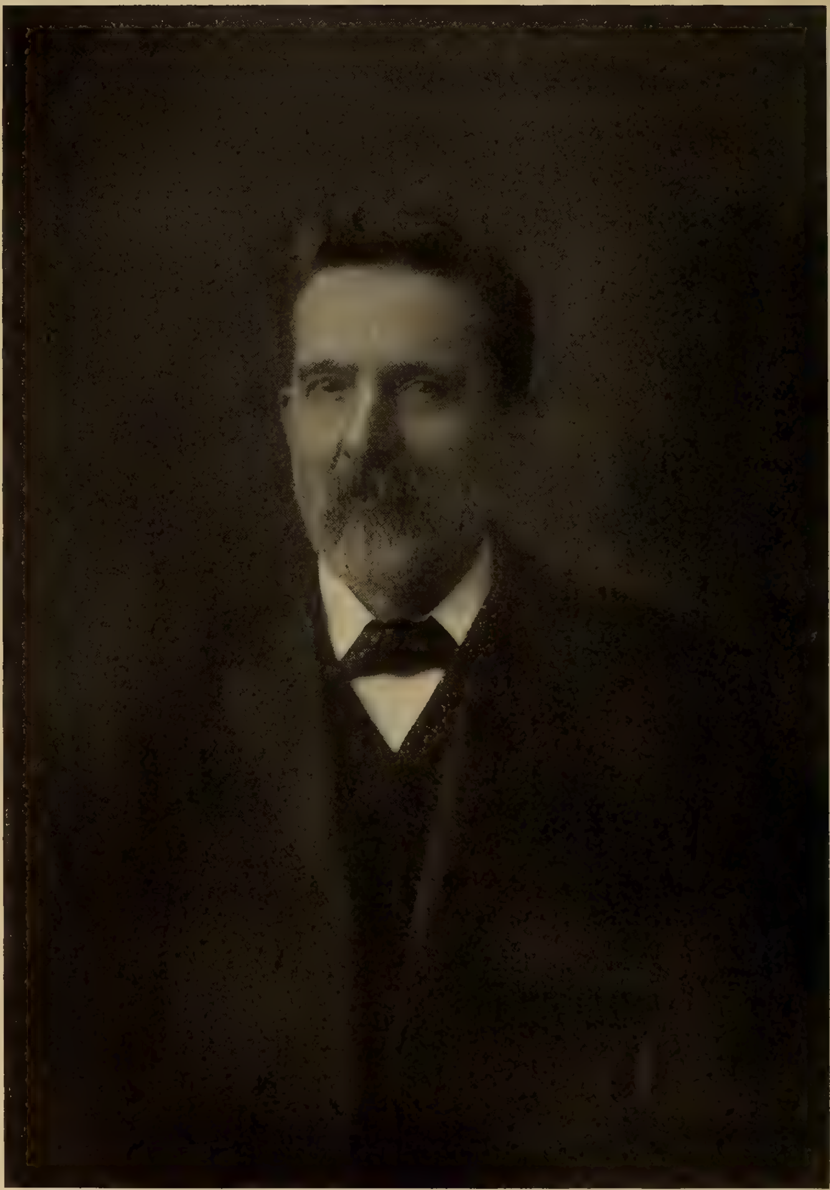
In 1880 he opened an office in Detroit as a consulting engineer and designed and built a high-speed steam engine, with shaft governor, using the inertia principle, since extensively developed; this engine having been put into operation in connection with a Brush dynamo, operating 40 arc lights, in 1883.

From 1884 to 1886 he represented the United States Electric Lighting Company in Michigan, during which period he installed a number of the early incandescent electric light plants, including one of 1,000 lights in the Stillman Hotel, Cleveland, Ohio, the first hotel in the United States lighted exclusively and continuously by electricity.

From 1883 Mr. Smith has been engaged as an expert witness in the United States courts in cases involving patent litigation, and this practice gradually developed until it displaced other lines of work, and in 1898 he removed to New York city and devoted himself exclusively to patent expert work.

Among notable cases in which he has acted as expert may be noted the following: Steam injectors, under the Hancock Inspirator patents; cylinder lubricators for locomotives; roller mills and middlings-purifiers for flour manufacture; cyclone dust collectors; quick-action air-brakes under the Westinghouse patents; pneumatic tires for automobiles; automobiles under the Selden patent; induction electric motors under the Tesla patents; pressure filters; incandescent electric lamps; steam-heating apparatus; typewriters; reinforced-concrete construction; the calculagraph, etc.

Mr. Smith became a member of the American Society of Mechanical Engineers in 1883. From 1891 to 1894 he served as manager of the society, and as vice-president from 1894 to 1896, and from 1899 to 1901, and he was chosen president at the annual meeting of 1908. He is also a member of the American Institute of Electrical Engineers, the *Société des Ingénieurs Civils de France*, the *Association des Anciens Eleves de l'Ecole Centrale des Arts et Manufactures,* the Detroit Engineering Society, the American Association for the Advancement of Science, the American Geographical Society, the Engineers' Club of New York, and the Ohio Society of New York.



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THE MODERN COTTON SPINNING FACTORY

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Among the mechanic arts that of textile manufacturing is at the same time one of the oldest and the most highly organized. It includes some of the most ingenious mechanical appliances, and its products are at the same time of commercial and artistic value. It is proposed, in the present article and in those which are to follow it, to give the present state of this important art in the district in which it has attained its highest development, and from which the other parts of the world have drawn their experience and success.—THE EDITOR.

THE art of spinning fibres into threads dates back beyond recorded history. Fabrics woven from threads are found in Egyptian and Chaldean tombs, and nothing can be said as to the earliest methods of spinning beyond, perhaps, that the first threads were twisted up by hand from a bundle of loose fibres pulled out by the fingers in a manner but little different from the method of the hand spinners of to-day, and that these threads, in the earliest weaving, were worked much on the system of mat or basket making from twigs or reeds. Until about 150 years ago spinning was carried out on lines but little different from those handed down from remote ages. Mechanically, there was a single spindle revolved by a wheel and band, but there was nothing in the shape of a roving: the thread was drawn out by the fingers from a loose mass of cleaned fibre. The modern cotton spinning factory consists of three departments: (a) a department for cleaning the fibre; (b) a department for spinning this fibre into threads. The latter department is simply a many-multiplied hand spinning spindle taking its supply of fibre from department (a) through the intermediary of a third department (c), which forms a series of extensions of (a) and (b) towards each other, and gives a more gradual transition of the cleaned loose fibre into the hard-twisted thread. According to the observed law of averages, any hundred casually selected articles will be more nearly the weight of any other hundred, similarly selected, than will two such articles be alike in weight. So in cotton spinning, the final thread produced by the mule or by the ring spinning frame, though primarily the result of the calculated reduction of so many pounds of cotton wool into so many hanks of yarn, is, secondarily, the average of many hundreds, or even thousands, of the primarily calculated threads. Thus, reduced so many times and laid parallel with themselves over and over again, the surplus thicknesses and deficiencies of the different threads average out into the even thread known as twist or as weft. When raw cotton arrives at the factory it is contained in

heavily pressed bales wrapped in coarse sacking and banded with hoop-iron, and it contains some seed, broken leaf, shreds of husk and more or less dirt and sand, not always innocently introduced.

When cotton manufacturing became a growing industry there was, perhaps, no special reason why it should settle in and round Southeast Lancashire; for no doubt the industry was widely spread at first, and we read of Arkwright setting up his mills at Cromford and Belper, for the people of Lancashire did all they could to destroy his machinery. But the climate of the county, its coal and iron, its excellent soft water and a certain energy in the people combined to give to Lacanshire a great advantage. Climate particularly favoured the industry, for cotton spins best in a moist climate. In dry air cotton fibre becomes harsh and refuses to lie peaceably with its fellows. If the air of a factory is too dry, it becomes statically electrified, and this causes the cotton fibres to stand out like quills on the fretful porcupine. And so, for good or ill, the industry possessed the County Palatine, and the county possessed the industry, and cotton spinning, weaving, dyeing or bleaching, or the trades attendant on these four branches of the cotton manufacture, make up most of the trade there is in the county. True there is woollen at Rochdale and round about, and there is cotton spinning in the teapot handle of Cheshire, in the northwest corner of Derbyshire, and, indeed, more or less all over the county, and even in Yorkshire and round Nottingham, Leicestershire and in the County of Stafford. But Lancashire is the locus *par excellence*, and, in Lancashire, Oldham stands pre-eminent for the standard yarns of sizes 28 to 32, these numbers, by which yarns are described, signifying the number of hanks of 840 yards contained in one pound of yarn. Cotton is spun as low as No. 4. Nos. 12 to 24 are termed coarse counts. Nos. 28 to 36 are termed Oldham counts. Fine counts are spun in Manchester and Bolton, and may run up to 250 or even 500, though 120 is considered fine. It is said that yarn of over 2,000 hanks per pound has been spun as a curiosity. It would be impossible, in the space of a single article, to give a description of the machinery employed for different counts. Suffice to say that its general lines are very uniform, minor differences in detail not visible to the casual observer alone existing. For example, throughout all operations there is the process of drawing the cotton between rollers, each successive pair of rollers rotating more quickly than the pair before it. According to the count of the yarn so must be the length of the staple employed, and, if the fibre or staple be, say, 1¼ inches in length, it would be broken if an attempt were made to pass it between sets of rollers only 1 inch apart. The roller centre distances must, therefore, approximate to the length of the staple, so that the sliver of cotton may easily be drawn out in passing through.

In this article, therefore, it is proposed to describe and illustrate the buildings and machinery of a modern factory. The size of a mill is always thus stated in terms of the number of spinning spindles it contains. The spindles of the preparation machinery of department (c) are not counted in this statement. Cotton, as it arrives at the factory, is simply a mass of curly, twisted, matted and pressed fibres, and the process of manufacture consists in cleaning these fibres, taking out their twists and curls, laying them all even and straight and parallel, and then twisting them into threads. There are in the main seven processes, and some of these are divided into multiple stages, while others are much alike in their characteristics. Every machine, however, may well be separately described which takes its share in the sequence of mixing, opening, cleaning, carding, drawing, slubbing and spinning.

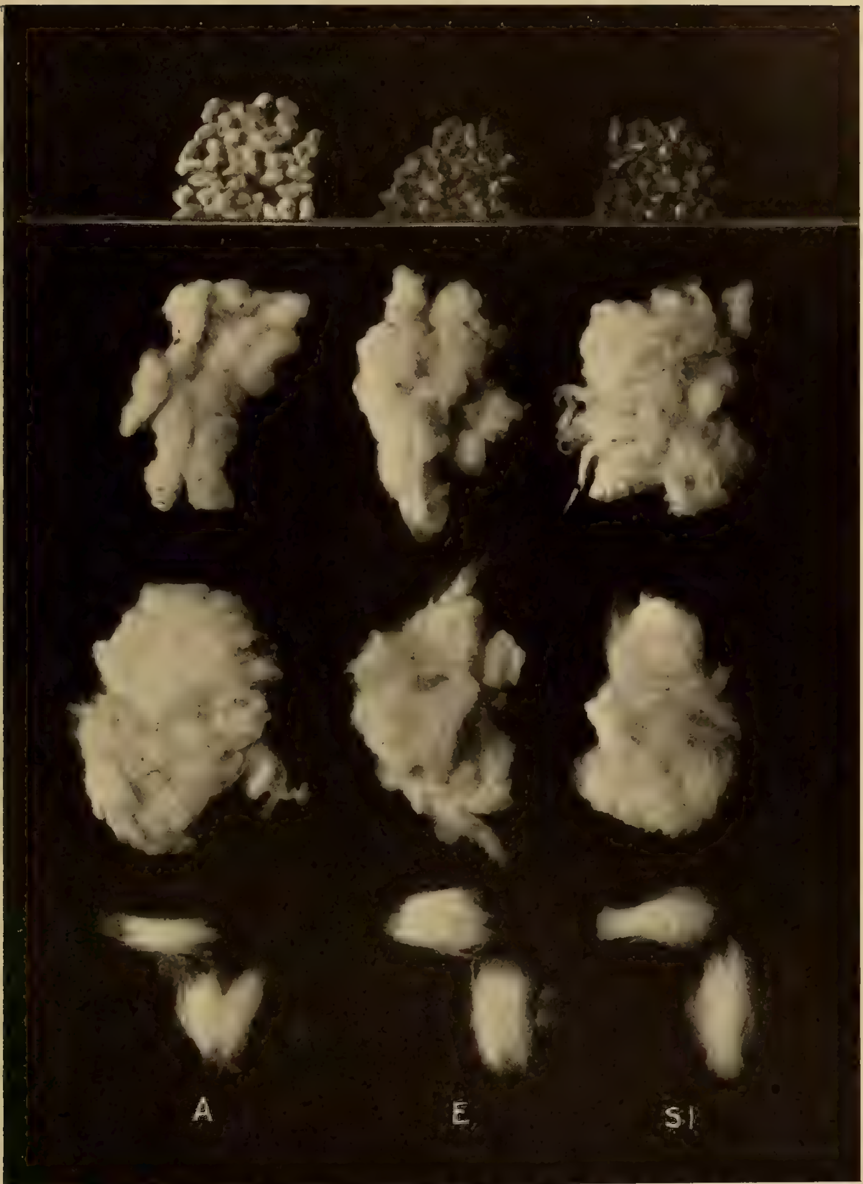


FIG. 1.—SEEDS, SEED COTTON, GINNED COTTON AND STRAIGHTENED FIBRES
A, American; *E*, Egyptian; *SI*, Sea Island Specimens.

Cotton fibre differs very much in length or quality. The highest class is the Sea Islands cotton, grown in Fiji, Tahiti, the Bahamas or the Florida coast. Its fibre has a length of 1¼ inches to 2¼ inches, and a diameter variously stated at 0.000833 to 0.00064 of an inch. It is soft and silky, and is used for the finest yarns. Egyptian fibre is also of fairly soft and silky quality, but is strong and tough, and makes good driving ropes. Its length is from 1 inch to 1½ inches m., and its diameter about 0.00065 inch m. Brazilian fibre runs from 1 inch to 1¼ inches. American

cotton—the main staple of the industry—varies from ¾ inch to a full 1¼ inches, while Indian cottons may be as short as ½ inch or less up to 1⅛ inches for the better varieties, and useful for the coarser counts of yarn up to about 28's twist. Upon the fineness of the yarn to be spun depends the sort of cotton that must be used, and upon the raw cotton that has to be treated depends the style of the cleaning machinery and the general operation of cleaning, the ratio of the different machines to be employed throughout the whole factory, and the details of the machinery, especially as regards the roller centres distances of all the drawing rollers. Substantially the process is alike for all varieties and all counts. In the finer counts there is introduced the additional process of combing, but this is the only difference of process throughout. Usuallv all the preparation machinery for three or even four spinning rooms can be contained in one room, extended, it may be, some distance beyond the width of the other rooms by a shed extension beyond one side wall of the mill.

GENERAL

Probably in no great industry is the machinery so varied and, in a sense, uneven in its degree of complication as in the machinery of cotton spinning. In the first preparation is found the combination of heavy rotating beaters, with the system of conveyance by a gentle blast of air of the material operated upon. And that very current of air is made to serve not merely as a transporting agent of the loosened fibres, but it is made to do duty in carrying off dust from the fibre, and, as in the scutcher, in effecting an even distribution of the material in the form of a thick blanket, the lap. Then in the carding engine the fibre is somewhat roughly treated by means of a multitude of light wire brushes, and, while the carding is effectually done, it is by no means easy to see just how this is contrived, nor is it very clear how the shorter fibres are flung off as waste or "fly" while the longer fibres find their way to the doffing cylinder. Consider for a moment the vital operation of drawing. The machinery for doing this is essentially but four lines of rollers easily and simply driven at different velocities. Beyond this there are only the very simple stop motions. The much less important machines, which serve simply to reduce the diameter of the sliver, are provided with most ingenious trains of mechanism—skew or hyperboloidal gears for spindle driving, a differential motion of repeatedly varying degree in respect of the differential of rotation, but of uniform differential of peripheral or surface velocity, and a most ingenious changing motion for the bobbin rail, which determines the double cone winding on the bobbins.

The actual operation of spinning is simplicity itself; yet how complicated is one of the machines by which the operation is carried out, and how very simple is the throstle or water frame of Arkwright, so called because it was first power-driven by waterwheels at Cromford, and because it was compared by the workers, as a singer, with the song thrush known in Lancashire and surrounding countries as a "throstle"! In this machine there are simply rollers, spindles driven from a plain tin roller, drag upon the yarn brought about by the crude expedient of power-wasting friction, and a copping motion given by a heart cam—that refuge of the idea-destitute mechanician.

How very different this from the self-acting mule spinning frame of Crompton as it has become to-day, the premier machine of the whole industry, which, in its one headstock, has gathered up such a collection of gearing, linkage, cams, detents, levers, scrolls, band wheels and other pieces of mechanism as never did before combine in one machine for the apparently simple purpose of turning three lines of rollers and a lot of

identical spindles at certain relative rates of rotation! What this complicated machine does, and does to very great perfection, can be done by a lady's two hands with a bunch of cotton wool and a single spindle. With one hand she will do what the rollers do in the self-actor; with the others she will carry out the work of the simply rotating spindle. The complicated mule will hardly make a better yarn than the lady; but the mule turns 1,000 or 1,400 spindles at one time, and, on each of them, winds identical yarn and produces a cop ready for the weaver's shuttle. A newcomer will need to watch a mule at work for several days before he can get a clear, connected picture of its many movements into his mind and grasp the special co-relation, on a time basis, of each movement, or even find out all there is of hidden details, detents hidden in a rotating box, motions, backing-off or stripping gears, stretch and other movements, all combining for better efficiency and greater output. It may appear wonderful that so complicated a machine as this mule, with its long-moving, spindle-carrying carriage, should be allowed to continue in use in face of the simple throstle or its rival, the ring frame. It does seem strange that, after the thousand or ten thousand foldings of the original scutched lap, there should be any further improvement possible in the evenness of the spun thread. But it is because of this possibility of further improvement that the mule holds its own. It does so because of a special and peculiar property of all twisted fibres. More turns per inch will run into a thin strand of fibre than into a thicker strand, as can very well be shown by taking a foot length of roving and attaching it to the same length of intermediate slubbing, when, by twisting one end with the thumb and finger, the thinner roving will receive by far the larger number of turns in each inch of its length. It is a further property of the fibre that the frictional grip of the fibres, one upon another, that is given by the twist in the smaller roving is considerably greater than the grip of the larger number of fibres with the smaller number of turns. Thus, if this piece of twisted fibre be pulled slowly out lengthwise, it will first begin to fail by stretching of the thicker portions. But as these pull out and become thinner, more turns run into the thinned places, which cease to extend. Another thicker part now begins to fail, and, assuming that a sufficiency of further twist is added to maintain strength, twist again runs into it and saves it before it breaks. Thus, bit by bit, every part of the thick piece will gradually stretch, by sliding of the fibres longitudinally upon each other, until the whole thread has been drawn out to an even thickness with the thinner length, and with the same number of twists per inch throughout. While still only half spun, a continuation of the stretching will continue to attenuate the thread, and always the most twist will run into the thinnest places and make them the strongest, thus compelling the thicker places to yield.

In a long rope walk, when a man casts a loop of tow over a horizontally revolving hook and pays out tow with his fingers from a bundle of fibre attached to his body, this action is carried out, for the man walks backward faster than he pays out tow, and he stretches the soft spun yarn to render it even. The man represents the traveling carriage of the mule, save that, in the mule, it is the spindles that are carried by the moving carriage, and in the rope walk the creel is on the moving piece and the spindle is stationary in place. This stretching action is one of the grand principles of the mule, its carriage, as elsewhere described, moving out from the roller beam faster than the front roller speed, so that the threads must break or stretch. They stretch, and observation will show the thicker places becoming reduced. Especially will this be ap-

parent when, as occasionally happens, quite a lump of fibre may come out from the rollers. Such lumps will cause breakage if they are short balls of badly-drawn stuff. But if they do not break they will disappear suddenly, having pulled out and taken twist. The machinery of a spinning mill, after the mule, is of no very special complexity. There is the winding frame, on which the small bobbins of yarn, spun on the throstle frame, are wound off upon large bobbins, to be set in the creel of the warping mill, which collects hundreds of threads in a certain order to form, in one long length, a band of parallel threads, which, when arranged properly in the loom, form the warp ready to be woven into cloth by the flying shuttle—the invention of Kay, a Bury man. But here the machinery ceases to be that of spinning, and this article is not concerned with weaving. From what has been said it will be clear that there is not any particular relation between the importance of an operation and the complexity of the means of carrying it out. Yet every machine is a survival and a development through many years of invention, improvement and demand, and its mechanism is devised to the best carrying out of an even and regular twisting of parallel fibres. It need hardly be said that every improvement in the preparation of the fibre has trenched more and more upon the superiority of the mule. But the mule still stands pre-eminent for the finer counts of yarn, as it stands first as a beautiful piece of mechanism for performing one of the prettiest of operations. Each time the carriage runs out over a mile of yarn is made, and a standard mill of 70,000 spindles averaging 32's will turn out 1,000,000 miles every week, or sufficient to envelop the earth forty times round the equator.

FIG. 2.—KAGOSHIMA MILL, JAPAN (BUILT BY PRINCE SATSUMA, 1866). THE FIRST MILL IN JAPAN. PLATT BROS., OLDHAM

As already stated, the home of cot-

ton spinning is the County of Lancashire. Owing largely to its climate, the atmosphere being by nature largely charged with water vapour, and to the particular genius of its inhabitants, Lancashire stands pre-eminent in the spinning of the cotton fibre, and the Lancashire machine makers cannot be touched in the excellence of their products. Unlike the machine-tool trade, which shows, generally, firms which make but a few tools, the biggest houses in the textile machinery trade make every machine that is required in a cotton-spinning factory. They have supplied these machines to every country in which cotton spinning is carried on, and Lancashire-made machinery is to be found in France, Germany, Italy, Austria, Spain, India, Japan and America, Brazil and Mexico, and also in China, Russia, Turkey, Greece and Portugal. Competition has, of course, been fostered against the Lancashire spinner; but the effect so far has been chiefly felt in the coarser qualities of yarn, and the tendency in Lancashire is towards the spinning of the finer and better qualities. Thus, where the town of Oldham at one time produced yarns from 24 to 36 hanks per pound, it is now quite common to find Oldham mills spinning 120's and 136's, the hank being a length of single yarn of 840 yards and the numbers or counts of the yarn signifying the number of hanks per pound weight of yarn.

FIG. 3.—OSAKA MILL, JAPAN (1888). PLATT BROS. & CO., LTD., OLDHAM

Whatever the counts spun, the general operations of the factory are identical. The finer counts demand the use of better fibre, and an additional process—combing—is now introduced between the operation of carding and that of drawing. The raw material or cotton fibre varies greatly, and the quality of fibre is very much a matter of the climate in which it is grown. Thus, from India the fibre is short and somewhat harsh, and it suffers also from

admixture of broken leaf and dirt, and this renders the cleaning more difficult. By the use of better seed the fibre can be improved, but the plants gradually deteriorate and the fibre soon falls back to that native to the locality, and cotton, grown in the Surat district from American seed, soon again acquires the characteristics which distinguish it as Surat. Good, fairly clean fibre of moderate staple comes from the United States in enormous quantities. From the littoral of the United States comes the Sea Islands cotton, which is characterized by length of fibre and a more soft and silky nature; and the next, but long, staple fibre, very soft and silky, and suitable for fine spinning, is the product of Egypt.

The cotton fibre, as grown, is enclosed in a husk or pod or shell somewhat like a soft-shell nut, the fibres enclosing a number of seeds, to which they are attached. The pods, when ripe, burst, and the fibre swells up to many times the size of the pod and is picked by hand. It has now to be ginned, to remove the seed. In one form of gin the balls of cotton are fed to a small roller, which drags the fibre from the seeds which cannot be drawn by the rollers into the narrow slit between the roller and a sharp-edged steel plate, which is presented to the rounded seed, while a second reciprocating plate pushes away and assists to strip the seed. The stripped seed falls from the rollers and the fibre passes through. In the saw gin a series of toothed discs, like circular saws, project through a sort of comb or slotted plate through which the fibres are dragged, leaving the seeds on the face of the comb, from which, when stripped, they fall away.

The ginned cotton, more or less mixed with broken seeds, parts of husk, leaf and dust, is then heavily pressed into bales; and this raw fibre, crushed and bent and compressed, is the raw material from which Lancashire manufactures cotton goods to the value of over £100,000,000 sterling annually for export alone.

Though the raw material arrives nominally graded as to quality, every bale differs somewhat, and, from every pod, fibres more or less short and immature are derived. It is necessary, especially with fine yarns, in order to secure an even product, that the raw cotton shall be blended, cleaned, opened up, and the short fibres removed. The short fibres from long staple cotton are used for the spinning of coarser counts. Thus the fibres rejected from the factory spinning 136's will be good for spinning medium numbers, and the waste from 60's will spin excellent coarse counts, and so on.

It is an axiom in cotton spinning that the biggest possible mixing should be made by mingling as many bales in one bin as can conveniently be done. From this mixing bin the cotton is raked down onto the floor and fed to the opener, which further cleans and separates the fibres, which are next well beaten in the scutcher and drawn clear of dust by a suction fan. Hence the fibre passes to the carding engine, which opens out the cotton into a filmy fleece, with every fibre separate and distinct, but not yet parallel. In spinning the coarser counts, the fibres are made to lie fairly parallel in the next operation of drawing, and no more fibre is usually rejected after the carding operation; but for finer work the carded cotton is combed, the shorter fibres are removed, and the long fibres are laid straight and parallel, and, after combing, there is no more fibre rejected. The operation of drawing ends the first preparation and delivers the fibre in the form of a sliver or loose, slightly twisted, soft round band of fibre about ¾ inch in diameter and just able to hold together. All subsequent operations are of the nature of spinning. Throughout the whole process every endeavour is made to secure an even product. Four of the first-made laps from the opener go to form a similar

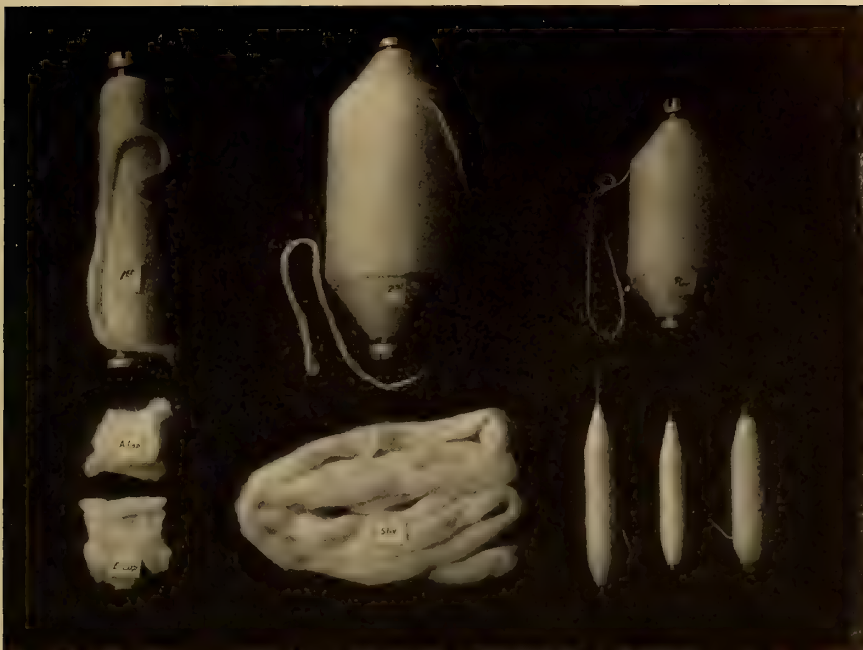


FIG. 4.—FIRST AND SECOND SLUBBINGS, ROVING LAP, SLIVER AND COPS OF MULE YARN
A, American Lap; *E*, Egyptian Lap.

lap in the second scutcher. Six slivers from the cards may be combined in a preliminary drawing operation. Eighteen or twenty of these slivers combine to form a sliver lap, and perhaps six sliver laps go to form a ribbon lap. Then the combed ribbon laps unite by sixes to form a fresh sliver, and six such slivers are drawn into one, and these, again, combined in six, and again in six, and, in subsequent operations, there is a series of duplications aggregating, perhaps, sixteen-fold, so that a thread of mule yarn may be the product of $4 \times 6 \times 20 \times 6 \times 6 \times 6 \times 6 \times 6 \times 16$, or nearly sixty million doublings of lap, every combination being accompanied by a greater ratio of drawing down, so that there is constant reduction of size, and the final product can only contain a mere fraction of any original over- or under-weight portion of the original feed to the scutcher or of any original lap variation.

So far as the Lancashire industry is concerned, the cotton fibre is nominally free from seeds, and the gin takes no place in a spinning factory, its use being confined to the country of origin, the seed being crushed for oil. The first operation in Lancashire is, therefore, the opening of the bales and the mixing of their contents preparatory to the cleaning operations, though there is considerable cleaning now done in the very first operation of breaking up the bales.

MIXING

There are two usual systems of mixing cotton. The object of mixing is to obtain yarn that has the necessary qualities and is made from cottons of a price that will yield a profit. Thus, the spinner can use American cotton, Indian cotton or fly, this latter being the shorter fibres which are carded out of longer staple material, in preparing this for the spinning of finer counts. Fly from good, long staple cotton may thus easily be better material than rough American or

Indian staple. In some mills each class of staple is passed by itself through the processes of opening and scutching. From this last machine the cotton is delivered in the form of a wide, thick, fairly even blanket, and several of these large rolls of blanket are then placed on the feeder of a second similar machine and are delivered from this machine in a final similar blanket, which is passed on to the carding engine. Mixing may be carried out at the scutcher, four American and two Indian rolls, or any other desired proportion, being passed together through the second scutcher, in which mixture is effected, the result being a lap of mixed cotton containing the desired proportions of each staple. Other spinners have large cages or bins into which, by hand, men fling the slabs of cotton they tear from the packed mass of a bale; but this custom is practically obsolete. They strew the material as evenly as possible over the area of the bin in alternate layers of, it may be, four American bales to one of fly or Surat. Twenty bales may go to a bin or mixing, and the mixed material is then raked down vertically from the door of the bin and fed to the opener, where it becomes better incorporated. All the laps fed to the second scutching or lap machine are, therefore, of the same nominal mixture, and such differences as they possess are averaged out by the feeding of several laps at one time to this machine. Probably there is not much to choose between the two methods, but by this latter method it cannot be known how much each particular variety of staple loses in the cleaning processes. By the former method this may be told with fair accuracy from the known weight of bales fed to the opener and the weight of laps delivered from the first scutcher. Some will feed the fibre direct to the opener from the bale; but it is, perhaps, wiser in all cases to break down the bales into a bin, whether for mixing or not; for, after all, this does help to average bales of the same nominal cotton, and it serves to discover stones, knives, matchboxes and sundry trifles not unknown to the cotton-opening loft. Thus there is, first, a loft above the bins, and from the bins the

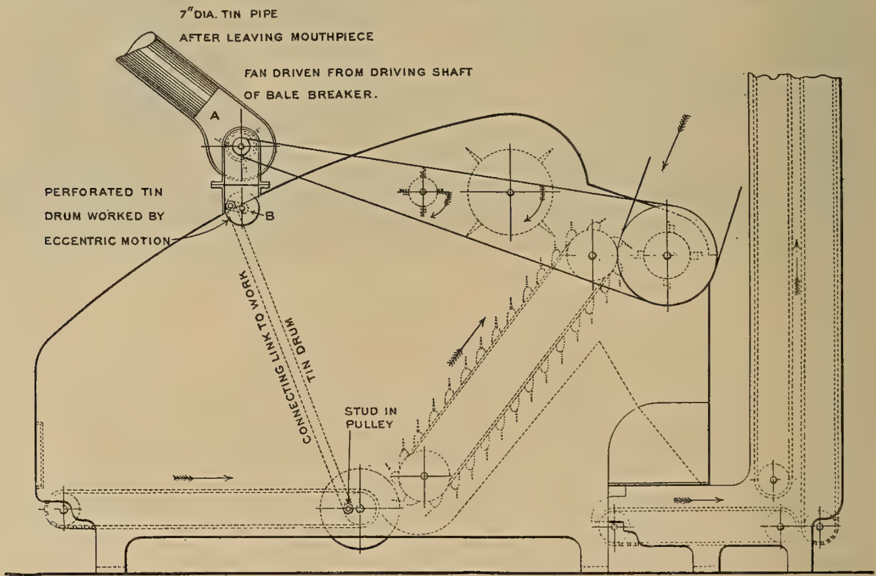


FIG. 5.—HOPPER BALE BREAKER, ASA LEES & CO., LTD., SOHO IRON WORKS, OLDHAM

staple is fed by hand to the opener. In a recently-built mill, spinning fine counts of 120's to 140's, the cellar of the mill is used as the mixing room. The bales of Egyptian cotton are opened at the end of a machine called a bale breaker, and slabs of the bale are flung into the hopper, Fig. 5. In this hopper there is a traveling lattice band carrying mately the whole of the fibre will be disposed of. As the lattice travels over the top roller, the spikes are now pointed downwards and easily part company with the fibre under the persuasion of a second revolving beater, which drives off the loosened pieces of fibre over an open-gridded surface through which dust and dirt fall. The loose cotton then falls upon

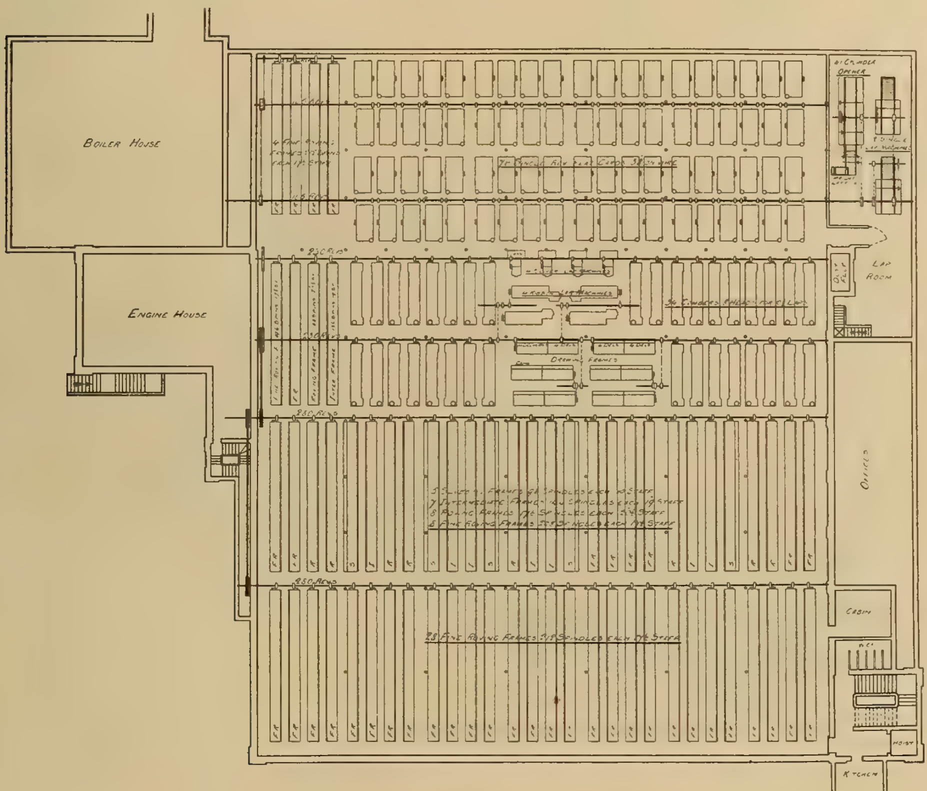


FIG. 6.—CAIRO MILL, OLDHAM. MACHINERY BY ASA LEES & CO., LTD.

acutely sloped spikes about 2 inches long. These spikes attack the lumps of matted fibre and carry them upwards. Arrived at the top of the hopper, the band travels under a revolving beater, and this beats off the projecting lumps of fibre and tumbles them back to the hopper floor, which is either sloped forward or has a slow forward movement of a lattice creeper, so that there is a constant supply of fibre pressed against the spiked lattice band; and ultianother lattice, which conveys it horizontally to a pair of vertical lattices, between which the fibre is held and raised to other traveling lattices and finally delivered upon a long combination lattice the different lengths of which can be made to move in either direction, thus enabling the fibre to be dropped into any one of several large cage bins over which this long lattice travels. The bale breaker has an exhaust fan above it, and this draws a current of air through the

tumbling cotton and frees it of much dust. The use of the fan is universal through all the cleaning machinery, for the air blast not only carries off dust, but it causes the flying fibres to deposit evenly upon the perforated zinc rotating cylinders in the scutchers, and so helps—indeed, is essential to—the formation of an even lap or blanket, in which form the fibre is delivered to the cards.

In the Cairo mill, Oldham, being simply a closely-spiked roller, and delivered upon the floor lattice on which the cotton from the mixing bins is hand spread. Thus the waste is evenly distributed among the fresh fibre and travels up with it between the pair of vertical lattices to the floor above or lap room. Here the double upright lattice delivers into a hopper feeder, which delivers to a combined opener and lap machine, and the laps from this

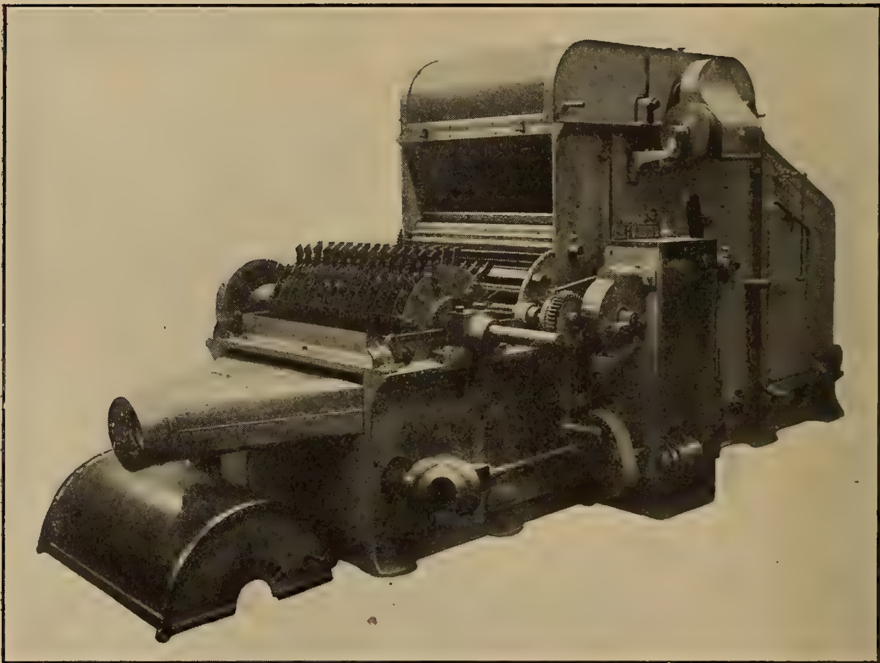


FIG. 7.—HOPPER FEEDER WITH PORCUPINE BEATER. DOBSON & BARLOW, LTD., BOLTON

Fig. 6, spinning fine counts, the machinery in the bale room below the floor illustrated consists of one hopper bale breaker, as above, delivering to upright and overhead lattices, and a breaking-up machine in which the waste of the roving and slubbing frames is torn up again. This waste is merely good material spoiled in the process of manufacture, and not waste in the sense of being inferior material. There is not much of it, and it is spread on a very slowly-moving creeper, passed through the beater cage, the beater are placed, four together, upon the feed lattices of two lap machines or scutchers (Fig. 18). This completes the outfit of the first series of processes.

The hopper feeder, Fig. 7, above named, is a machine not unlike the bale breaker. In the hopper is a swinging spade or plate, against which the cotton in the hopper presses. According to the pressure, so the position of this swinging plate, which in turn controls conical feed drums and regulates the amount of cotton passing forward. This is

the first regulation of the weight of fibre per unit length. This hopper feeder, Fig. 7 spreads the cotton on the feeder lattice of a combined Buckley opener and lap machine, Fig. 8. In this machine the cotton is beaten by a revolving spiked beater and delivered upon the face of an exhausted zinc cylinder, which passes it on to the scutcher beater. This consists of a pair of, or sometimes three, steel flat bars fixed to the ends of a number of arms, the diameter of the beater being 20 inches. The flat edges of the beater bars strike the cotton as it comes through a pair of heavily weighted, small fluted rollers. The rapid blows knock out any remaining seeds, which are driven through the gridded cage in which the beater revolves, and the scutched fibre travels forward upon an exhausted cage and is finally delivered of fairly even thickness to a set of rollers, which roll the loose blanket of cotton or lap upon a small roller into the form of a cylinder about 41 inches long and 24 inches diameter. These laps, as they are termed, are placed four or five upon one lattice feeder of a second scutching machine and pass through another beating, and this machine delivers a similar finished lap, which is now ready for carding.

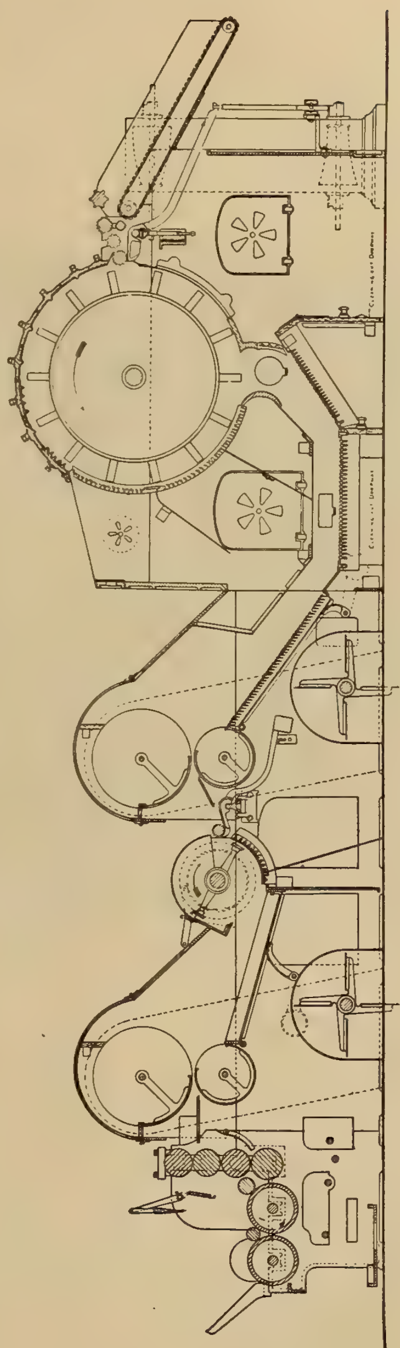


FIG. 8.—SECTIONAL VIEW OF A BUCKLEY OPENER AND LAP MACHINE. HOWARD & BULLOUGH, LTD.

OPENING

The operation of opening or willowing, once performed by beating the cotton on an open grid with willow spikes, was next carried out in a machine named a devil, a willow or an opener. In this machine the fibre is fed steadily and continuously into a cage of iron bars, in which there is a rapidly revolving cylinder covered with projecting round, blunt spikes, as in the Oldham willow, with horizontal shaft; or the rotating beater is built up of a series of iron discs armed round the edge with flat, projecting steel bars. Fans draw a current of air through the cage and remove dust, the beaters drive out seeds by velocity, or break up

pebbles and drive them through the bars. In the willow the cotton was fed in measured quantity, beaten for a time and turned out through an automatically-opened door loosened and fluffed out into light, clean fibre. The modern opener of the Crighton variety, Fig. 10, feeds the beaten cotton forward up a tapered, barred cage of increasing diameter, and sometimes away to a second beater, and delivers the cleaned fibre ready for scutching.

In the course of the passage of the beaten fibre through an opener there are revolving cages of perforated sheet metal from which the fan exhausts air, and the beaten fibre, driven in a cloud from the beater cage of bars, settles on the perforated cylinder cage and parts with its dust, the cage carrying forward the cotton to the delivery point. Cotton must not be beaten too much. In the Crighton opener the draught of the fan is so regulated that it only draws the cotton from the beater cage when the fibre has become sufficiently light and open. Thus when sufficiently beaten, it is drawn away before being injured. Sometimes the opener has been combined with a scutcher beater, a questionable advantage unless combined with regulating apparatus; for if any use is to be made of the lap produced the cotton must be weighed to the opener upon a brattice, a brattice being a traveling chain of wooden laths or "lats," one lat painted black every four or five feet, and between such painted lats a given weight or fibre being spread. Thus the opener is given a continuous feed, and, while this is good in its way, there is always the greater variation of error, owing to dirt, than when the first weighing is performed on the brattice of the first scutcher after most of the dirt has been removed in the opener.

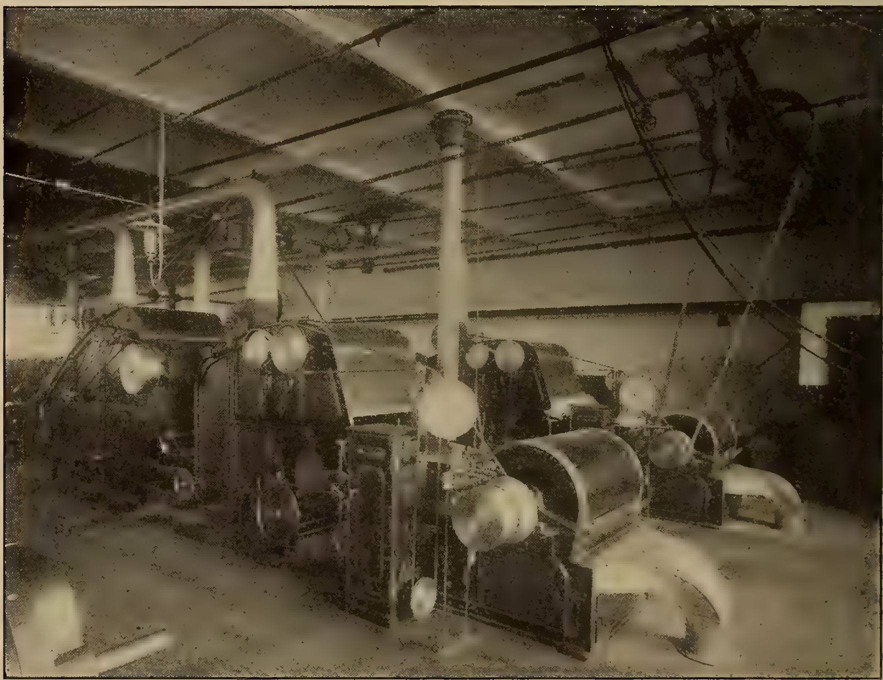


FIG. 9.—COMBINED BALE BREAKER HOPPER FEEDER AND PORCUPINE OPENER WITH REGULATOR.
ASA LEES & CO., LTD., OLDHAM

These remarks apply rather to coarser counts and older methods.

With the preliminary bale breaker and the hopper feeder with the swing ing spade feed regulator, the combination of opener and a single beater scutcher appears to have become established practice, especially for fine counts, as previously described.

While the various machines illustrated are those made by different makers, it is not usual to fit up a factory with machines of different makers. Thus, the Cairo mill, of which Fig. 6 is the card room, was fitted throughout by Asa Lees & Co., of Oldham. Similarly, Platt Bros., of Oldham; Dobson & Barlow, of Bolton; Howard & Bullough, of Accrington, and John Hetherington & Sons, of Manchester, fit up mills complete.

Other firms, like Brooks & Doxey, of Gorton, and Tweedales & Smalley, of Castleton, do not make every machine, nor do Lord Bros., of Todmorden, or Taylor, Lang & Co., of Staleybridge.

Every machine maker has some special machine in which it is customary to say among spinners that special excellence is reached. Then, again, while it would be unusual to find two different makers of, say, mules or of speed frames, in one mill, it will be quite usual to find one maker fitting up all preparation machinery, while another puts in the mules and a third, perhaps, supplies the ring spinning frames. But machinery of the same order is not usually obtained from more than one firm.

In passing through both lap machines the weight of fibre per unit of length of lap is regulated by means of a motion known as a piano motion, and consisting of a series of levers or pedals, Fig. 14, which press up against a roller just behind the feed rollers to the beaters. The cotton passes between these pedals and the roller above, and the pedals are more or less depressed from the roller, according as a thick or thin layer of fibre is coming through. To each pedal pad hangs a rod, Fig. 12, at the lower end of which is a tapered length, and all these tapered rod ends are packed side by side in a narrow frame with roller divisions, Fig. 13. Thus, if all the rods are lowered at once, the length occupied in the frame will be considerably altered, and similarly, but in the opposite sense, if all rods are raised at once. As the 41 inches of roller breadth is divided up into a large number of pedals, each little section of lap is taken care of by its own pedal, and some pedals are up and others are down, and the end movement of the frame is only the algebraic sum or difference of the various rod end breadths at the roller centres in the frame. The device integrates the many movements of the rod ends, and the net end movement of frame is a mean of the whole up-and-down movements of the many pedals, and

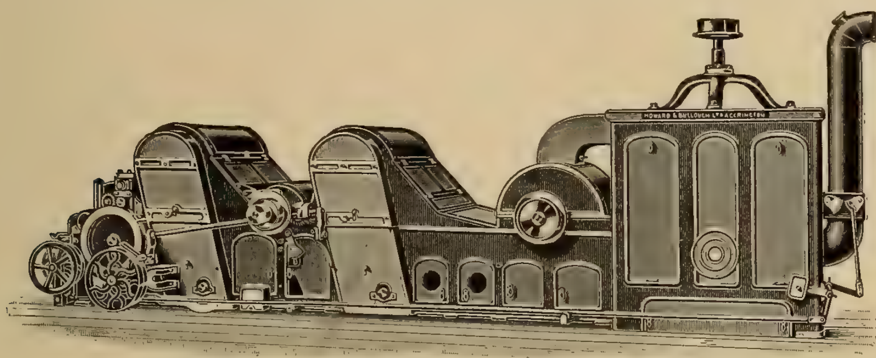
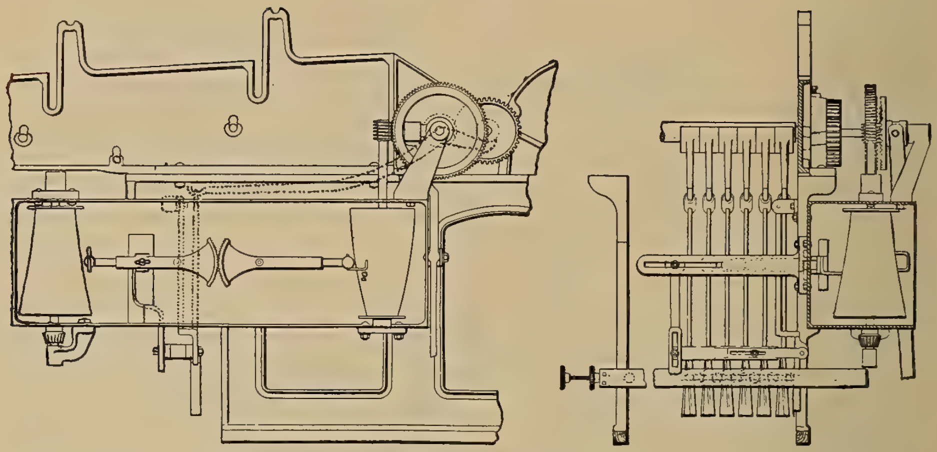


FIG. 10.—CRIGHTON OPENER; HOWARD & BULLOUGH, LTD., ACCRINGTON



FIGS. 11 AND 12.—IMPROVED SELF-ACTING "PIANO" FEED REGULATOR WITH COMPOUND GEAR FOR FEED ROLLERS, AND TRIPLE ANTI-FRICTION BOWLS FOR REGULATOR. HOWARD & BULLOUGH, LTD., ACCRINGTON

this end movement shifts a belt on a pair of small cone drums, Fig. 11, and changes the rate of feed. Howard & Bullough do not use two feed rollers next the beater, but make the lever pedals act the part of the lower roller, thus getting the regulation action right up to the beater, as in Fig. 14.

thoroughly beaten. The seed is less liable to be crushed than when the feed is through a pair of rollers, cleaning is better done, and the cotton rendered more fleecy, which, of course, eases the work to be done in the subsequent operation of carding. The system of Fig. 14 is modified to Fig. 15 for long staple cotton, but

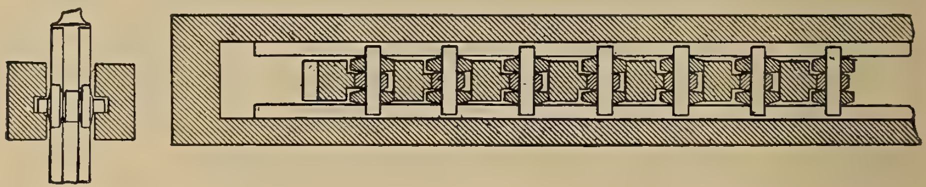


FIG. 13.—FRAME WITH ROLLER DIVISIONS, SHOWN ON LARGER SCALE. HOWARD & BULLOUGH, LTD.

They also employ the method of Fig. 16, which they term the tandem or double grip. In this device the cotton is held by two sets of pedals or holders. From one the fibre is beaten. From the other, which is set behind, there is no beating of the fibre, but these rear grippers are connected with the regulating gear and serve to shift the cone belt just about the time that that part of the lap arrives at the beater which has influenced the moving of the belt. The double grip is also claimed to prevent plucking in of lumps of fibre before they have become properly and

Fig. 16 is regarded as offering considerable advantages in good regulation. It will be noted that the shock of the beater does not come upon the regulating pedals, and this serves to prevent plucking in of tufts of unbeaten cotton.

Asa Lees & Co. employ a different combination in their regulator. Each pair of pedal rods is attached to the opposite ends of a short lever or link, and the middle points of the links of two pairs of pedal rods rest on the two ends, respectively, of a similar link of twice the length, and again two of these double-length

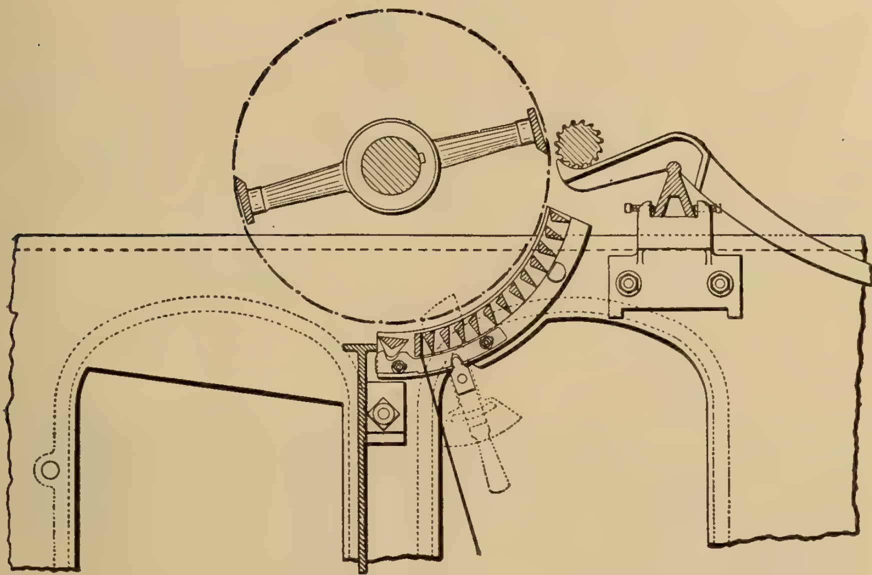


FIG. 14.—ARRANGEMENT OF FEED ROLLERS AND COTTON HOLDERS FOR SHORT AND MEDIUM STAPLED COTTON BEATEN FROM PEDAL NOSE, SHOWING ALSO ADJUSTABLE AIR GRATE UNDER BEATER. HOWARD & BULLOUGH, LTD.

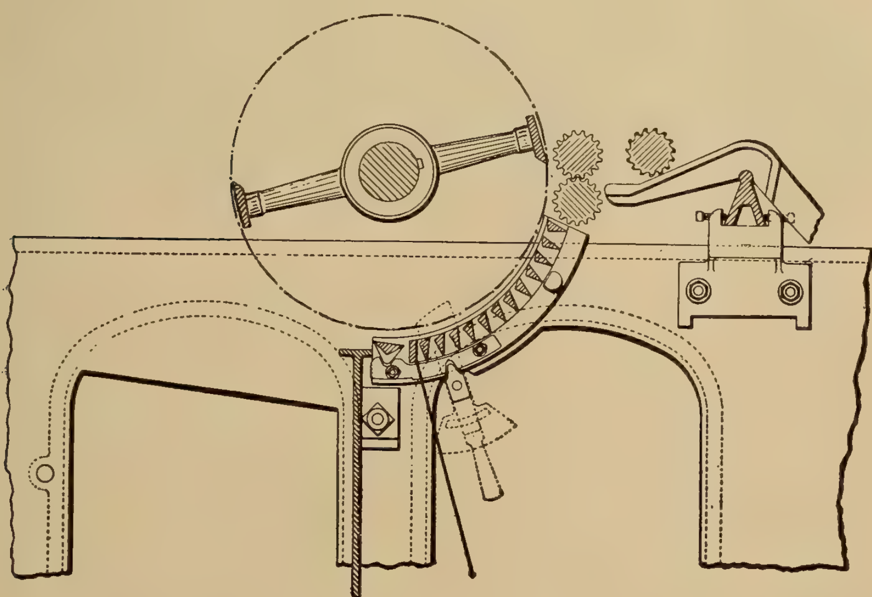


FIG. 15.—ARRANGEMENT OF FEED ROLLERS AND COTTON HOLDERS FOR LONG STAPLED COTTON, BEATEN FROM FEED ROLLERS, SHOWING ALSO ADJUSTABLE AIR GRATE UNDER BEATER. HOWARD & BULLOUGH, LTD.

links rest respectively on the ends of a link of double their length, and this final link, as seen in Fig. 17, couples direct to the strap shifter of the small cone drums. In the illustration, Fig. 17, the traveling feeder lattice is removed, the four carrier rollers appearing above the regulation levers. One blade of the beater is seen beyond the roller, and below this roller are visible the top faces of the piano lever pedals, the link connections hanging below and their arrangement being clearly visible, together with their coupling, up to the weighted lever which shifts the belt on the cone drums which drive the feed roller. The grip roller is not merely fluted, it is also toothed.

Again, this is simply an integrating device, and the same result is obtained by John Hetherington & sons by means of wires instead of rods, a looped wire round a small pulley being attached by its two ends to the ends of two adjoining pedal levers. Each link carries two wire pulleys or bowls, and is pivoted at its centre to a larger frame, which carries two bowl frames, and so on to the final frame, which is connected directly to the cone box.

These motions do not regulate the evenness of the lap as regards its thickness right across, but they regulate the amount of material which is fed to form a given length of lap. Regulation of the thickness equality at all points is fairly well carried out by the exhaust cages or drums on which the fleecy fibre settles in proportion to the amount of air tending to each part of the cage. Naturally, the air rushes to the least thickly covered areas and carries the fleece with it. When coarser counts are spun, the scutchers may each have two beaters in series; and, for very dirty cotton, such as some of the Indian cottons, the fibre is cleaned in a Crighton opener, which contains one or two vertical conical beaters in grid cages. These machines are not so suitable for long staple cotton, and much less beating is, of course, required by clean cottons, such as Egyptian. It is not desirable to do more beating to any cotton than is necessary to clean it. With fine counts the output per spinning spindle is so comparatively light that the blowing-room machinery is relatively very small in quantity, as compared with coarser count blowing rooms,

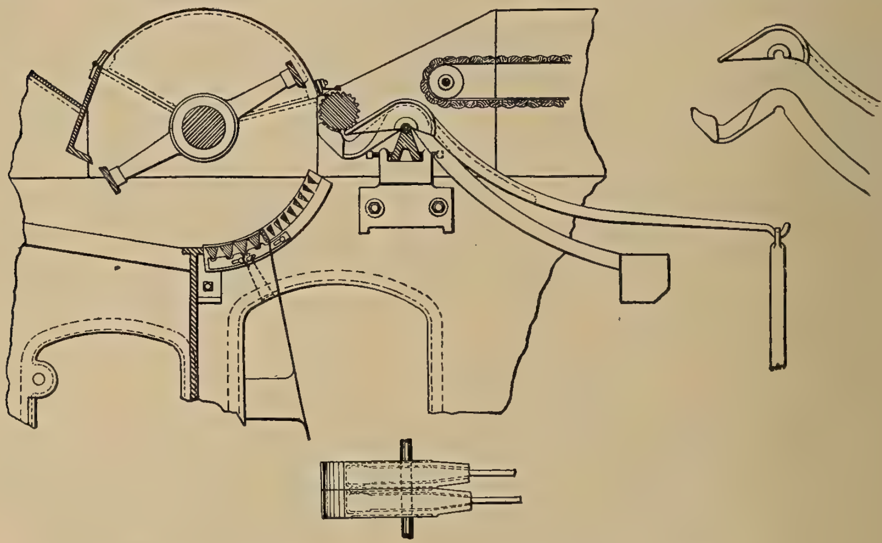


FIG. 16.—DOUBLE-GRIP COTTON HOLDERS TO REGULATOR. HOWARD & BULLOUGH, LTD., ACCRINGTON

where not only must more cotton be worked, but it must be worked to a greater extent than necessary with cleaner raw material.

The foregoing sequence of operations, as carried out by Asa Lees & Co.'s machinery at the Cairo mill, may be somewhat modified in other mills by different arrangements of openers and scutcher beaters, but substantially it represents ordinary modern practice. The main difference between a coarse and a fine mill is in the ratio of the machinery. Here, for example, is a list of the machinery in two mills of finer and coarser counts.

In the finer mill the blowing room contains one bale opener, two hopper feeders, two openers with attached lap machine and six scutchers, with 108 cards, 9 drawing frames, 794 slubbing spindles, 2,558 intermediate and 10,552 roving spindles. This preparation machinery supplies 101,-608-mule spinning spindles in three rooms producing 45,000 pounds of yarn per week. Of these there are 36,848 spinning weft averaging 85's counts, 21,560 twist spindles averaging 62's, 19,440 twist averaging 46's, and 23,760 averaging 45's weft, the finer counts in each case being spun from Egyptian and the coarser from American cotton. These mules occupy three floors of the mill and all the preparation goes upon one floor. In a coarser mill spinning 27's, the 55,600-ring frame spindles are almost all contained in the space of one floor, and all the preparation, except mixing, occupies one floor and includes 2 bale breakers, 3 hopper feeders, 3 openers, 24 scutchers, 106 cards, 15 drawing frames, 1,000 slubbing spindles, 2,272 intermediate, and 7,200 roving spindles. The weekly output of the 55,600 spinning spindles is 96,000 pounds, as compared with the 45,000 pounds from the 101,608 spindles of the fine-counts mill. Thus from about one-third the space filled as compared with the preparation, there is turned out over double weight of yarn, and, as between the two mills, each coarse spindle turns out nearly four times as much yarn as does a fine spinning spindle.

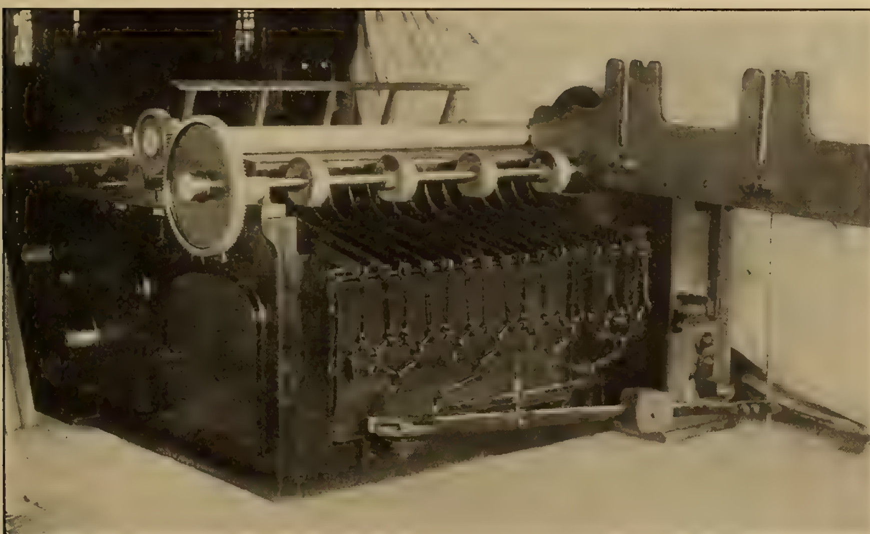


FIG. 17.—"PIANO" REGULATING MOTION AS ARRANGED BY ASA LEES & CO., LTD., FOR LAP MACHINES

In still finer mills it is found necessary to add to the area of the room

containing the preparation machinery in order that this may all be contained on one floor.

To this end there is a shed extension of the ground floor room made beyond the general plan of the floors above.

This extension is made beyond one side wall of the mill, the lower part of the wall being omitted and replaced by heavier columns of iron. The extension is usually occupied by the cards, which do not require so much light, and the roof of the extension is unglazed, so that there is no risk of drip, which would ruin the card wire. Where the extension joins the main body, however, a single high-pitched shed, saw-tooth light is introduced to throw light across the ground floor so as to compensate for the light lost in the extra breadth of floor.

In a mill spinning 36's on mules, such a card room, with extension, serves four rooms of mules with 112,284 spindles.

As regards the general dimensions of a mule mill, a very usual breadth is 135 feet, divided into bays of 22 feet 6 inches, 22 feet 6 inches, 15 feet 0 inches, 15 feet 0 inches, 15 feet 0 inches, 22 feet 6 inches, 22 feet 6 inches by rows of pillars as shown in the Cairo mill, Fig. 6. This enables the line shaft in the mule room to be carried by one of the two middle rows of pillars, while the countershafts lie exactly in the centre line of the mill and drive right and left down to the mule headstocks at equal angles of belt.

A spinning mule has all its driving mechanism near its mid-length, there being at the Cairo mill in one mule of a pair 602 spindles on one end of the carriage and 546 on the other end, and in the other 616 and 532, respectively. Since, in a pair of mules, each mule carriage faces its fellow, this unequal carriage length throws the long ends of each carriage opposite the short ends of its fellow and the two headstocks are thus displaced seventy pitches from each other, In this mill the pitch, or gauge, as it is termed, is 1 and 5/16 inches, and there are 1,148 spindles across the mill. The passage at one end is only 11½ inches, that at the other 3 feet 2 inches. The same effect in placing the driving of each side of a mule at an equal angle may be obtained by making the inequality of spindles alike and varying one of the central bays.

The mill breadth is thus fixed by the machinery itself: the length of the mill may be anything in reason and depends upon the number of the machines. A simple extension of length by any fraction adds an equal proportion to each floor. Similar differences occur in the other floors, on one of which the spindle gauge is 1⅛ inches, and the difference or displacement of the headstocks is 7 feet, or 84 spindles. This headstock displacement is necessary, because the projection of each headstock is more than half the floor space of a pair of mules.

The 1,338 spindles of 1⅛-inch gauge of the Cairo mill may be compared with the 1,350 spindles of the No. 2 Marlborough mill fitted by the same firm, Asa Lees & Co., in a mill 1 foot wider, viz., 136 feet.

Before leaving the subject of the blowing room, however, it may be pointed out that the whole of the fans in the different machines discharge their dust-laden air into sheet-metal pipes, which conduct it into a dust chamber, from which there is a large sieve-protected outlet area to a dust tower. The heavier dust is chiefly sand, dirt and small fragments of bad fibre, leaf and bits of husk. Seeds and heavy dirt collect in the base of the machines below the grids of the beaters and are removed as they accumulate. At the point where this digression was made, the fibre had been followed to the time when it leaves the blowing room and is ready for carding. In the best appointed mills these laps, with an iron rod through their central axes, are placed vertically in a carriage,

which runs on a single floor rail and on an overhead guide rail and carried through a passage, closed by fireproof doors, into the card room, which is best on the same floor as the scutchers. The laps are laid horizontally to the cards and here begin the finer processes of the art, though it is not to be thought that the rougher processes already described are not fully as important, for on good mixing and careful regulation of weights the final accuracy of the yarn much depend.

and drawing operation, the several laps being drawn down to one, and their irregularities averaged out to the beater. As in the first beater, the feed apparatus is a traveling lattice on which the various laps rest and are unwound at the speed of travel of the lattice. All wastes, such as the ragged ends of laps, are, of course, returned to the feed of the first scutcher.

Regulation of the feed to the second scutcher was performed mechanically and automatically with

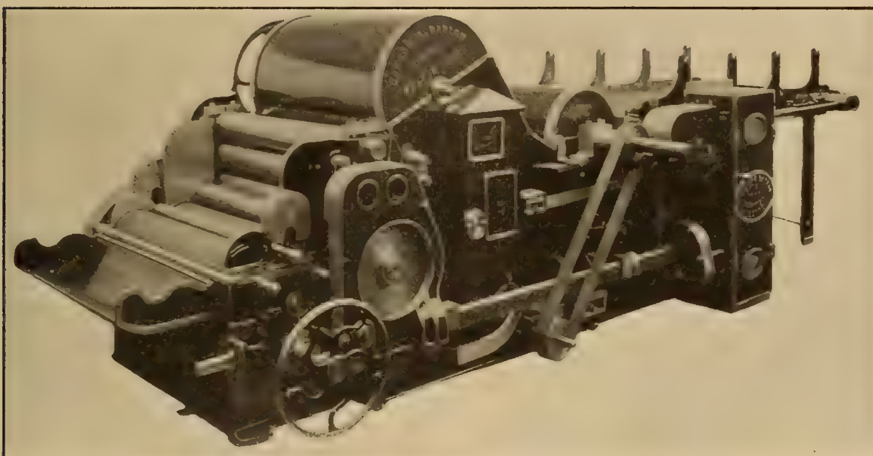


FIG. 18.—SINGLE-BEATER SCUTCHER. DOBSON & BARLOW, LTD., BOLTON

much more ease than with the hand-spread fibre of the first operation, for the several laps are fairly even and of themselves give a fairly even average layer through the fluted feed rollers, especially since the universal adoption of the piano motion. Essentially the blowing room is as it was thirty years ago. Openers and scutchers are identical in principle and general appearance.

In the old system the opened cotton was weighed out, as already described, upon even lengths of a traveling lattice. This weighing and spreading was an arduous operation and was the first operation in determining the final counts of the yarn to be spun. The hopper feeder has dispensed with hand weighing, and, combined with the piano-motion feed roller regulator, secures correct weights of lap. On the old as in the new system, the finisher scutcher, Fig. 18, was fed with several laps from the first scutcher and delivered one lap ready for carding.

Finishing scutching was once practically the first mechanical averaging

Improvements are there by the hundred, but the main principles survive. The chief changes are the bale breaker and hopper feeder. These machines are additional upon old practice and are now almost universal.

(To be continued.)

MACHINE GROUPING AND FACTORY LAYOUT, AS AFFECTING COST DATA

By C. H. Stilson

WITH his factory operating full blast and with a cost system in which not a single item of expense is overlooked, a manufacturer is prone to experience a sense of satisfaction as to future profits. He knows that there are practically no idle machines and that he is selling his goods at a selling price comfortably above commercial cost as calculated from his carefully-gathered cost data.

Yet it is quite possible that this very cost data, so carefully (and sometimes expensively) gathered, may give selling prices which will bring about, at the year's end, a considerable decrease in expected profits. For, whereas his cost data will give the general condition of the shop and of the individual departments, they will not indicate a certain specific condition which, if it exists, will work subtly to destroy profits. This evil has to do with the apportionment of department burden or overhead cost.

Writers on the subject of cost-finding principles and methods differ as to those principles that underlie the apportionment of overhead cost. Some advocate the use of the percentage plan, in which are determined the ratios between the overhead costs and the prime or productive labour costs. Others denounce this method as founded on fallacious reasoning, holding that burden costs are in no sense proportional to the productive wages, but vary instead with the time, or productive hours.

The percentage system is without doubt more widely used than any other, so that many of those reading this article will no doubt find the subject to have phases which touch conditions in their own factories. Moreover, there are certain classes of manufactories in which the type of product and the existing wage system seem to make the use of the percentage plan both proper and preferable. Manufactories of textiles, shoes, screws and small metal novelties, which manufacture from stock on a piece-work basis and with automatic machinery, come into this class, and it is with such that this discussion deals most closely.

The evil condition mentioned above as existing in many such shops, to the detriment of all earnest endeavor at the determination of actual costs, will be found in the different departments into which these shops may be subdivided. More often than otherwise, and especially in concerns organized years ago, the departmental subdivision has been the subject of no study; departments grew and spread along with and by reason of the ability and progressiveness of the respective foremen.

As each of the departments grew about the foremen, the class of work and the machinery became more and more heterogeneous, with frequent unnecessary duplication of machinery as a result. The many evils of this state of affairs are too well known to need repetition; let us discuss only the effect of such lack of organization on shop cost data, and try to set up a few guide-posts which shall direct the way to improved conditions.

With the percentage method of treating burden cost in the shop departments, records are kept of the productive labour by departments, this labour being all such labour as

has been expended upon operations taken into consideration when figuring selling prices. All other labour expense, whether by producers or by non-producers, is a burden expense, and, when added to the indirect material expense of the department, such as supplies, etc., should give the total department burden cost. The ratio of burden to prime labour cost will, of course, vary considerably with the class of work performed, whether by hand or by machine; it may be 50 per cent. for sorting against 400 per cent. for highly-complicated machinery operators. That is, it varies inversely with the output and directly with the amount of attendant expense of the nature of non-productive labour and repairs.

In many factories where the departments have been allowed to grow unchecked, as described above, each department has become a small shop, undertaking practically all classes of work. Obviously, the cost data records from such rooms will be of just the same mixed nature as the class of work done therein, and the burden cost will, in fact, partake of the nature of an average or "mean burden." A moment's analysis of such a room will indicate that the percentage burden for same, as shown by even the most careful cost system, cannot be normal for all of the classes of work attempted, and whether it is normal for any class is just as uncertain.

It is evident that among selling prices figured by means of such "mean-burden" percentages will exist a great number which are either above or below the price that would be dictated by actual costs, so that, in bidding for orders, the price quoted will be sometimes too high and other times too low. The tendency will accordingly be to repel those orders on which the profit has been thus unconsciously increased, and to attract by low bid all orders on which the profit is actually much less than desired. Thus, little by little, the shop becomes filled with orders on which the profit is partly or wholly imaginary; likewise, at the year's end the dividends are unaccountably less than expected, much to the amazement and perplexity of all. The likelihood of the occurrence of this evil is directly proportional to the size of the orders.

Disregarding all other issues, such as the effect on clerical force, supervision, etc., it becomes evident that the subdivision of shops into separate departments should theoretically be carried out in extreme detail if we are to ascertain the normal burden for each class of work. This is, of course, impracticable with factories of the size usually met with, and our only recourse is to group our work and machinery into departments, satisfying ourselves with a compromise between what theory dictates and what economy demands. That is, we can put into the same department all work that requires the same, or nearly the same, burden of the nature of supervision, clerical work, truckmen, tool-setters, etc. This will reduce the expenses for foremen and clerks, and will make the cost data records from each room approximately correct for the classes of work done there.

Such reorganization or re-subdivision of a factory into departments in which the above-mentioned classification of work and machinery is carried out should be attempted only after the most thorough analysis of equipment and product has been made. Like estimating, it is a matter of the judicious use of records, coupled with some considerable practical knowledge. Perhaps the following general statements may be helpful in forming a basis for judgment in attempting to classify work and machinery in such shops as we have chosen for discussion.

Most authorities agree as to the principles to be followed; machinery should be classified by speed, character (automatic or hand-fed), attention required by operator or toolmaker, etc.; work should be classified by class of operator, attention required by foreman, clerks, etc.

MACHINERY

Speed.—On the matter of speed it would be obviously unwise to form a mixed group consisting of foot-presses and high-speed blanking presses. The output by pounds from the cutting presses would far exceed that from the foot presses, from which it is plain that less attendant help in the form of truckers and labourers would be necessary for the foot presses than for the cutting presses.

Character.—The matter of construction and operation likewise dictates the proper grouping of machinery. It would be wrong to put a number of automatically-fed machines into the same group with hand-fed machines. In the former case, one operator could perhaps attend to several machines, while it might be possible that two operators would be required to attend one hand-fed machine. From which it is evident that the product of the first operator would require from four to six times the attention from tool-setters, etc., necessary for the product of the other two.

Attention Required.—In some cases tools may be adjusted in a press and run for a week with very little further attention. Evidently such a machine is out of its class with other machines on which a high-priced workman is constantly employed keeping tools in order.

WORK

Class of Operator.—The wages paid may be said to vary according to the skill of the workman. It therefore quite often happens that a shop department has in it a mixture of skilled, semi-skilled and unskilled producers, with the wages varying accordingly. This brings about a condition of inequality, in that the output of the high-priced workman must often bear more than its share of the department burden; the grouping of operators should therefore take this point into consideration.

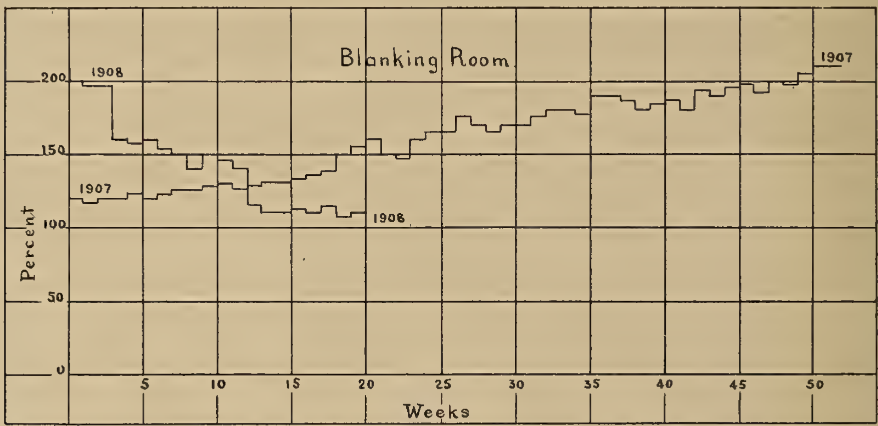


FIG. 1.—CURVE OF BURDEN EXPENSE FOR EACH WEEK IN THE BLANKING DEPARTMENT

Attention Required.—The different classes of work, in the matter of attention required by foreman, clerks, handy men, etc., are subject to the same laws as govern the grouping of machinery. For example, one girl may spend ten hours inspecting a few pounds of very small articles, while the girl next to her may have a dozen or twenty different sorting jobs weighing a total of several hundred pounds. Evidently the former requires much less attendant help than the latter.

With the foregoing points in mind, the departments may be gradually remoulded and the work and machinery properly classified. Nothing is more interesting than to watch the change

from week to week in the department percentages as the rearrangement proceeds; this may be done by use of the well-known charts by which comparison is so easy and comprehensive.

The diagram in Fig. 1 shows burden expense for each week in the blanketing department. During 1907 this percentage constantly rises. Early in 1908, by applying the principles of classification, the curve is made to drop. The abrupt changes at the fourth and thirteenth weeks would indicate the removal of whole groups of machinery accompanied by high burden costs. The curves of some other departments would show correspondingly sharp upward changes.

Hand in hand with the grouping of machinery comes the proper location of the different groups, a very important point also.

For example, the receiving room and the raw material stores room should be adjacent; likewise the finished material stores room and the shipping room. The other departments or class groups should then theoretically occupy such positions between the two above-mentioned stores rooms, that the work could progress naturally from raw state to finished product with a minimum of retrograde movement.

The diagram in Fig. 2, although theoretical, is applicable to a shop manufacturing small metal novelties in which the sequence of operations would be—

1. Blank.
2. Clean.
3. Stamp or form.
4. Clean and electro-plate.
5. Assemble parts together.
6. Japan, paint or lacquer.
7. Assort or inspect.
8. Store or ship.

Where factory buildings run up a number of stories, the problem becomes more complicated, and, of course, each shop becomes a specific case requiring analysis of the product and present equipment of buildings and machinery. One agrees at once, however, that the heaviest machinery and the work of the most bulky type should be confined to the lower floors. A plan sometimes followed in high factory buildings is to have the work descend from floor to floor as its condition approaches finished product, shipment being made from the ground floor directly into drays or freight car.

It is on such cost-finding matters as the foregoing that the engineer displaces the bookkeeper; and the farther one goes into the subject the more does it open up unfolding new problems for both the engineer and the bookkeeper. No sooner is one phase of the subject thoroughly threshed out than our advanced knowledge enables us to see some new condition, the influence of which on the matter in hand cannot be overlooked.

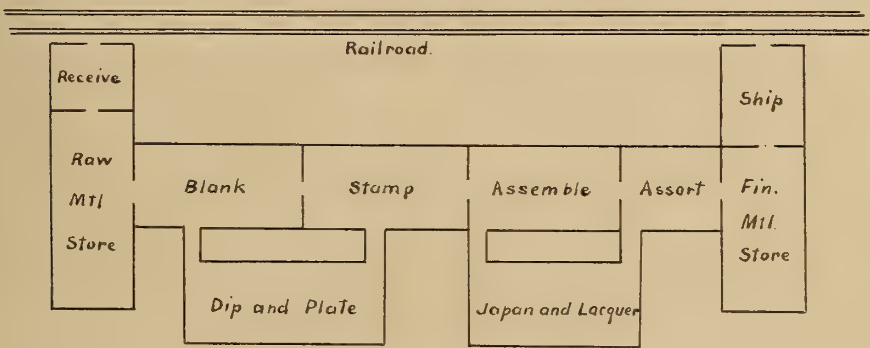


FIG. 2.—THEORETICAL FACTORY LAY-OUT

MODERN STEAM TRACTORS FOR RAPID AND LIGHT ROAD HAULAGE PURPOSES

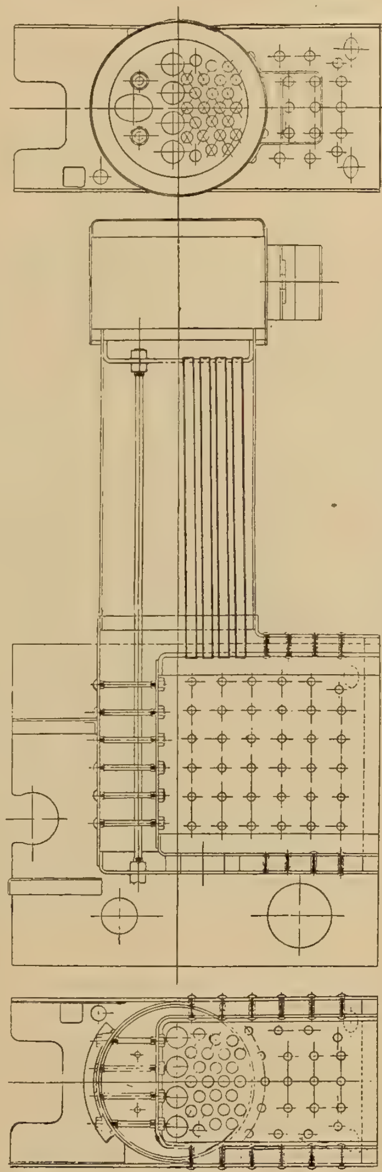
By William Fletcher, M. I. M. E., Author "Steam Locomotives on Common Roads," "Steam Carriages and Traction Engines," etc.

SOME years ago the author contributed an article to this journal on "Modern Traction Engines." The present paper deals with another type of road engine for smaller loads, and for running at quicker rates of speed. These small road locomotives are termed steam tractors, to distinguish them from the heavy traction engines dealt with in the earlier paper. In 1896 the Light Locomotive Act of Parliament was passed in order to free light, self-propelled road vehicles from the irksome laws in force, which had been enacted for the regulation of the heavy engines. Soon after the light locomotive act was passed, the tractor sprang into being, in order to avail itself of the more lenient laws, intended more particularly for steam wagons, but these wagons do not come under review in this instance. Since 1896 the steam tractor business has grown in leaps and bounds to its present proportions. It is now an important engineering industry, and most of the makers of tractor engines are engaged in the manufacture of steam tractors. In the 1896 Act of Parliament, the tare weight at first allowed was not to exceed 3 tons; the engines made according to this regulation, however, were not perfectly satisfactory, owing to their lack of weight on the driving wheels, so that sufficient adhesion was not obtained for the tractor to draw a greater load than that suitable for a pair of horses. In 1904 the tare weight of steam vehicles was raised to 5 tons by the Local Government Board. When the 5-ton tractor became legal, the economy and efficiency of the vehicle were assured. A marked saving was earned over horse haulage.

There were light tractors constructed many years previous to 1896, but these came under the ordinary traction engine laws. They were consequently not permitted to travel at more than 2 miles an hour when passing through towns or villages, and 4 miles an hour in the open country. Nearly thirty years ago the writer saw a light steam tractor mounted on wood wheels, weighing 5 tons. The vehicle was silent when traveling, it was chain-driven and had been at work for a considerable time. More recently another tractor could be named, the weight of which must have been under 3 tons. Messrs. John Fowler & Co., Leeds, also turned out a number of small locomotives weighing under 5 tons. Some of those made in 1878 are still in daily work and are working under the new regulations. These tractors are driven by duplicate spur gear on each driving wheel, the advantage of which is, the driving wheels having a spur ring bolted near the tire, the wheels, the fixed axle and other parts can be cut down in weight, but this system is not adopted in the modern tractor. The main wheels are driven through a live axle, which system allows the tractors to be mounted on springs. One of Messrs. Fowler's tractors was exhibited at the Manchester show of the R. A. S. E. in June, 1897. The engine there exhibited was constructed in 1878 and has been in regular use ever since. The engine still retains the original motion work, the fire-box and boiler are in good condition. Messrs. Fowler

claim to be the pioneers of the tractor industry.

The locomotive type of boiler is the one universally adopted for tractors at the present time. Figs. 1, 2 and 3 represent the boiler manufactured by a well-known firm and will serve as an example of the rest. It is intended for a compound engine to work at 200 pounds steam pressure, the hydraulic test pressure amounting to 350 pounds per square inch. It is constructed of best Siemens-Martin mild steel plates. The plates are flanged by hydraulic machinery at one heat; the riveting is done by hydraulic, portable and fixed riveting machines. No punched holes are allowed by the best makers, the holes being drilled through the plates in position on vertical drilling machines, two or more holes being drilled at the same time. The circular seams are generally double riveted, except at the smoke-box end, where single riveting is suitable. All the longitudinal seams are double riveted. Solid frames for the fire-box bottom and fire hole are used. A ring of square section wrought iron, as shown by Fig. 2, is used for the smoke-box end. The fire-box stays are pitched 4 inches apart, the well-known bridge bars for the roof of the fire-box are abandoned and vertical stays adopted in their place. The stays are screwed and riveted into the fire-box shell plate, and screwed into the fire-box top with nuts for making the joint on the inside. This form of staying allows the fire-box top to be more readily cleared of scale. Two longitudinal stays are used, with nuts inside and outside of the front and tube plates. The fire-box sides or horn plates are carried upward and backward, fitted with flanged cross-plates. These horn plates are drilled in position for the bracket bearings, which are turned to fit the holes, the bolts or rivets merely keeping the castings close to the plates, but the racking strains are taken by the thick plates. Four large tubes above the smaller ones are intended to conduct a portion of the flame to the smoke-box, where the consequent great heat will mix with the exhaust steam and cause it



FIGS. 1, 2 AND 3.—TASKER'S "LITTLE GIANT" STEAM TRACTOR. END AND SIDE SECTIONAL ELEVATIONS OF BOILER AND FIRE-BOX. TASKER'S, LTD., ANDOVER, HANTS.

to pass away in an invisible form. The water space around the fire-box is 2 inches wide. Four mudholes and a manhole, with suitable lids, are provided. A sliding or a swinging

fire door and a smoke-box door that can be tightened all round are necessary. The flanged plate beneath the smoke-box carries the forecarriage and the axle-swivelling gear.

Before dismissing the boiler, some mention should be made of further details, as shown on Fig. 4, to a larger scale. The cross-plates in-

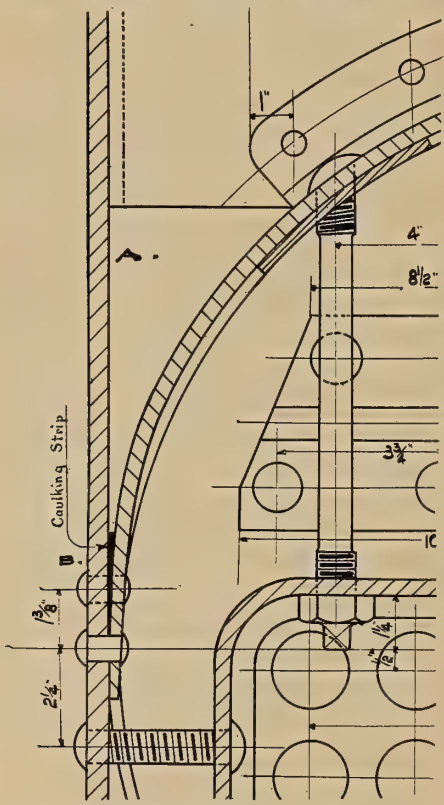


FIG. 4.—DETAILS OF CONSTRUCTION OF BOILER. TASKER'S, LTD., ANDOVER, HANTS.

serted between the side plates are attached to the boiler crown plate. The roof stays are also illustrated. A wedge-shaped strip of soft iron is inserted between the side plate *A* and the arch plate at *B*, to facilitate the caulking of this important portion of the boiler; the longitudinal double seam of rivets passes through the wedge plate and forms a satisfactory piece of workmanship. A safety fusible plug is inserted in the fire-box crown plate. In order to suppress the emission of sparks, the smoke-box is extended in length; a spark catcher should be fitted to the chimney top. The chimney is made of thin steel plate. In some cases it is made from top to bottom in one plate; the bell mouth on the top is of polished brass.

Messrs. Aveling & Porter, and Messrs. Fowler & Co., both use the "Bellpaire" form of fire-box for their compound tractors, as illustrated further on.

The general arrangement of the tractors made by all the firms presents a similarity of appearance. This arises from the fact that all the makers have adopted the locomotive boiler, and by general consent the cylinder is placed near the smoke-box end of the boiler, while the shafts and gearing are disposed in the wrought-iron box bracket at the fire-box end of the boiler. Fig. 5 represents the latest type of compound tractor made by Messrs. Aveling & Porter, of Rochester. The cylinder in this instance is provided with a flange all round the base for bolting to a seat riveted on the barrel of the boiler. Most of the makers provide a seat for the cylinder; they are generally made of cast steel, and riveted to the boiler shell. Instead of the bottom of the flange being chipped and bedded to the boiler, the seat and cylinder foot are both planed, making a thoroughly sound piece of work, and particularly valuable for export purposes.

The cylinders, whether of the single or compound type, are well steam-jacketed and drained; the steam inlet elbow is usually placed as near to the smoke-box tube plate as practicable. Ample room should be provided round the liners, and in the stop-valve chamber, arranged at the highest part of the cylinder, to form a reservoir or dome, so as to prevent priming. The cylinder casing and the liners are cast separately of hard iron. The former is bored and the latter turned. The liners are forced into their place by hydraulic pressure. It

is important that the steam passages and ports should be of sufficient area to admit of a high piston speed. For this reason small ports are useless. The openings are too cramped for the steam to pass in and out of the cylinder freely; the result is, the slide valve is forced off its face and the engine primes as soon as any great speed is attained. The clearance spaces, however, should be reduced to the utmost limit, for unless this is attended to there can be no great economy. Now that steam pressures are gradually being raised, the piston-rod stuffing-box packing must be of the special metallic type as used on some high-speed and high-pressure engines. To prevent the condensation of steam in the cylinder and valve chests, the whole is coated with some non-conducting composition and covered with sheet-steel plates. The throttle valve (if governors are required) is arranged in the upper part of the cylinder. A pair of spring-weighted safety valves are mounted on the top cover of the cylinder, as shown in the next illustration of Messrs. Brown & May's single-cylinder tractor, Fig. 6. Our remarks thus far have been applicable to single or compound cylinders. Most of the firms are prepared to construct compound tractors working up to 200 or 220 pounds pressure, and these engines are recommended because of the economy of fuel and water they effect. The design of the cylinders varies somewhat. The cylinders are placed side by side, the slide-valve chests are arranged outside, so as to be easy of access for examination or repairs, as in Messrs. Aveling & Porter's and Robey's engines, Figs. 5 and 24. In some instances the slide valves are placed in the upper portion of the cylinder casing.

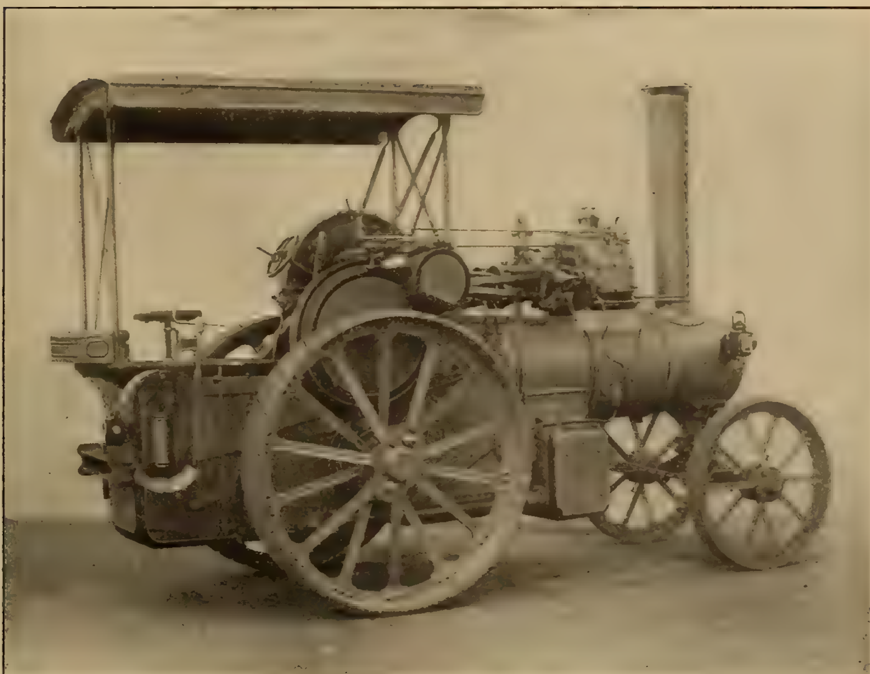


FIG. 5.—COMPOUND STEAM TRACTOR. AVELING & PORTER, LTD., ROCHESTER

The slide-valve faces are set at an angle, the spindles being above the centre line of the cylinders, the faces are inclined and made to point to the

centre of the crankshaft. In other cases the valve faces are flat, the valves being arranged above the cylinders; they are inclined towards the front so as to meet the requirements mentioned above. The top cover in both these types, on being lifted, exposes the stop-valve, throttle-valve and slide valves to view.

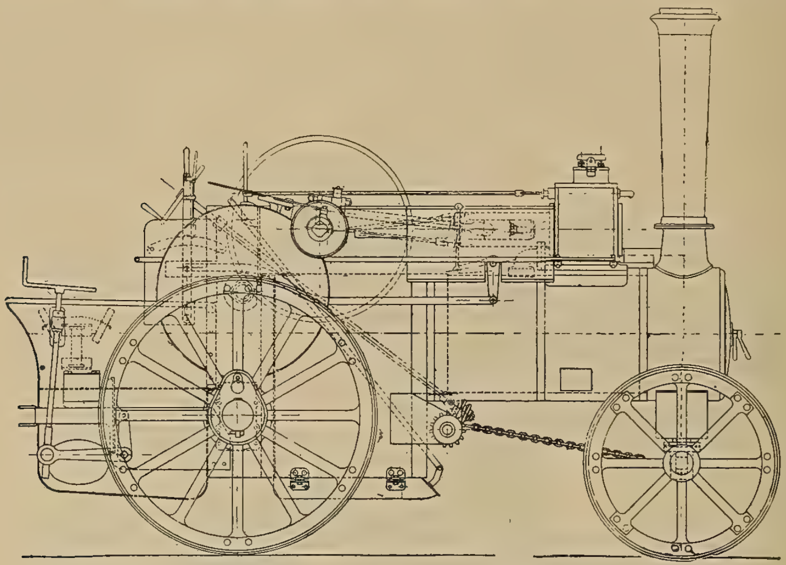


FIG. 6.—BROWN & MAY SINGLE-CYLINDER TRACTOR

Among the advantages of the double-crank compound engine, the following may be named: There is no dead centre, they are fitted with an auxiliary valve to admit high-pressure steam to the low-pressure cylinder, so that the engine can be started with the cranks in any position. The auxiliary valve may be opened when the tractor is starting with a load, or when climbing a steep hill, the engine working as a double engine and giving off its maximum power. The uniform speed of rotation given by a double-crank engine is an advantage in work. With the compound cylinders the steam is expanded and utilized practically to its last limit, consequently it escapes silently into the atmosphere. One steam tractor, made by Messrs. Green & Co., of Leeds, is fitted with a compound engine, arranged tandem fashion. Fig. 7 gives a section of the cylinders, which are steam jacketed; a dome is cast with the cylinder casing above the liners. The stop-valve is placed in the dome and takes steam from the highest point. Messrs. Green's engine will be dealt with further on.

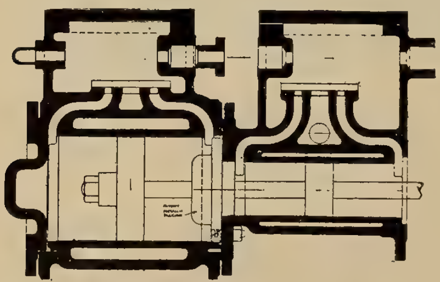


FIG. 7.—TANDEM COMPOUND CYLINDERS. GREEN & CO., LTD., LEEDS

The pistons for the various tractors are made of cast iron, steel, or wrought iron; the rings are of different types. Messrs. Brown & May's pistons have a plate inserted between the expanding rings. This prevents the great leakage when the rings become worn.

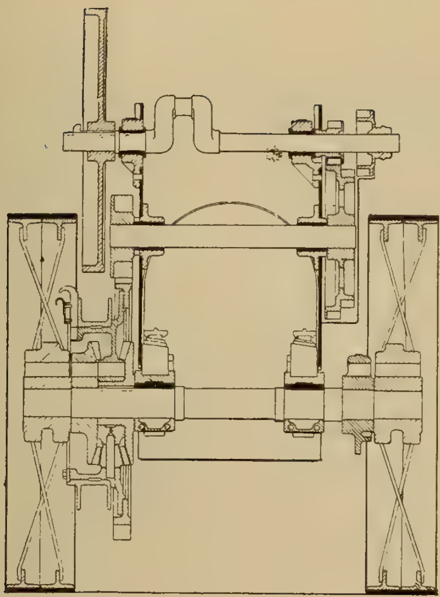


FIG. 8.—TRANSMISSION GEAR OF GREEN'S COMPOUND STEAM TRACTOR

Cast steel is generally employed for the cross-head; the slippers are of brass or cast iron.

This brings us to the subject of the transmission. All the modern tractors are built on the three-shaft system, that is, a crankshaft, one countershaft and a main axle. Fig. 8 shows a cross-section of a tractor. It will be seen that all the gearing is placed outside the wrought-iron box brackets. On the right-hand side of the crankshaft are two first-motion pinions, which gear into a double-spur wheel on the countershaft beneath. The two pinions on the crankshaft are cast separately. They slide on keys cut out of the solid material. The small or slow-speed pinion is generally provided with a long boss, with keys cast on the outside; the large or first-gear pinion slides on these keys and passes over the small pinion. (See Fig. 12). Neither of the pinions can be put into gear until the other is drawn out; the lever for actuating the pinions (but not shown) has a locking arrangement.

On the left-hand side of the countershaft a pinion is keyed gearing into the spur ring which carries the compensating gear centre. The combined winding drum and compensating gearing will be mentioned presently. Fig. 10 illustrates the compound steam tractor manufactured by Messrs. Chas. Burrell & Sons, of Thetford, which gained the gold medal in the recent R. A. C. trials. This interesting engine is built on the three-shaft system; the first-motion pinions are actuated by a patented clutch gear, invented by the makers. The cylinders and all the top-motion work are neatly boxed in to save them from wet weather or dust when traveling continuously on the highway. There are several novel features in this tractor, one of which is the lever and clutch for locking the compensating gear from the foot plate. Coming back to the combined winding drum and compensating gear, all tractors are fitted with this combination device and, in addition, the drum

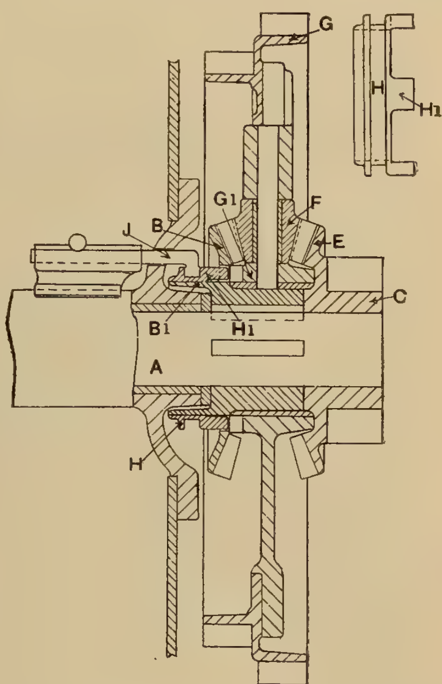


FIG. 9.—THE BURRELL LOCKING ARRANGEMENT FOR THE COMPENSATING GEAR

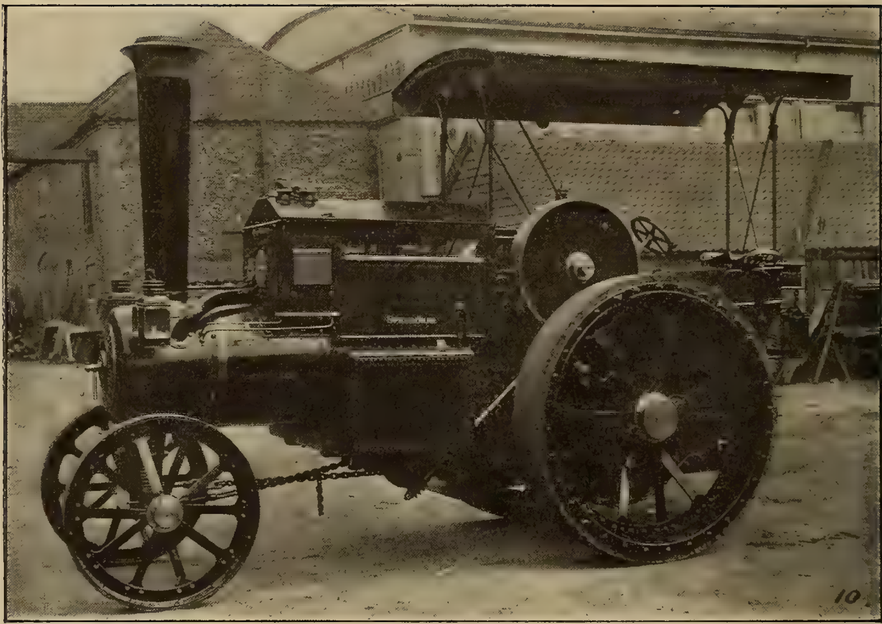


FIG. 10.—MESSRS. C. BURRELL & SONS, THETFORD. COMPOUND TRACTOR

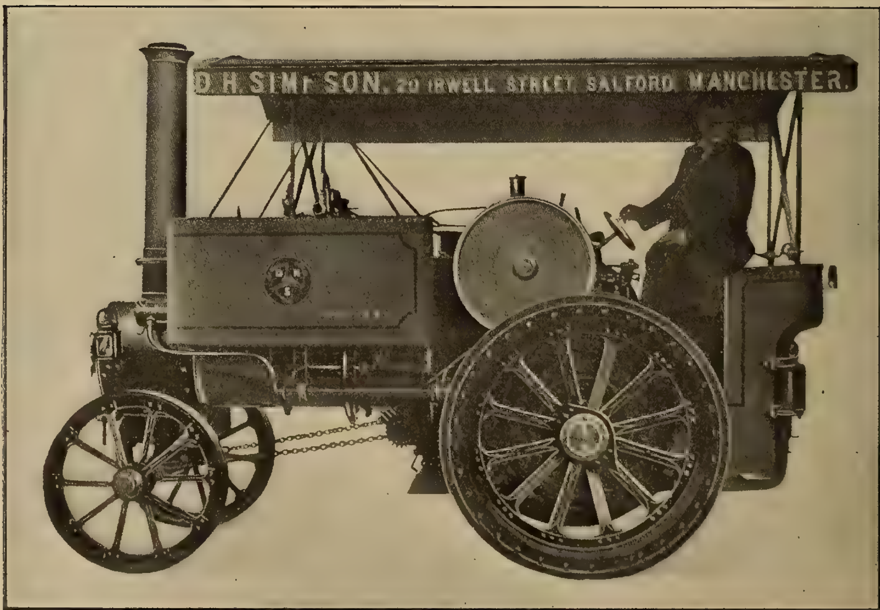


FIG. 11.—COMPOUND TRACTOR, FITTED WITH IRON WHEELS WITH BLOCK TIRES.
MESSRS. W. FOSTER, LTD., LINCOLN

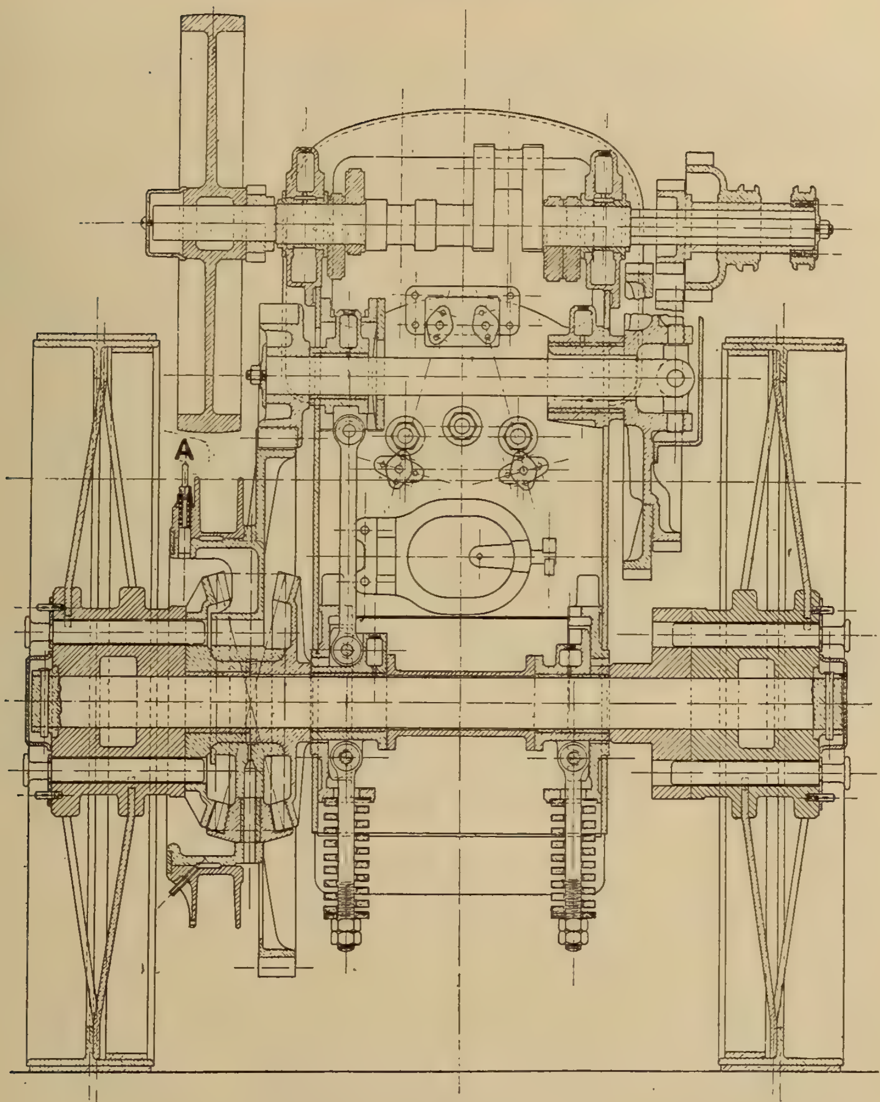
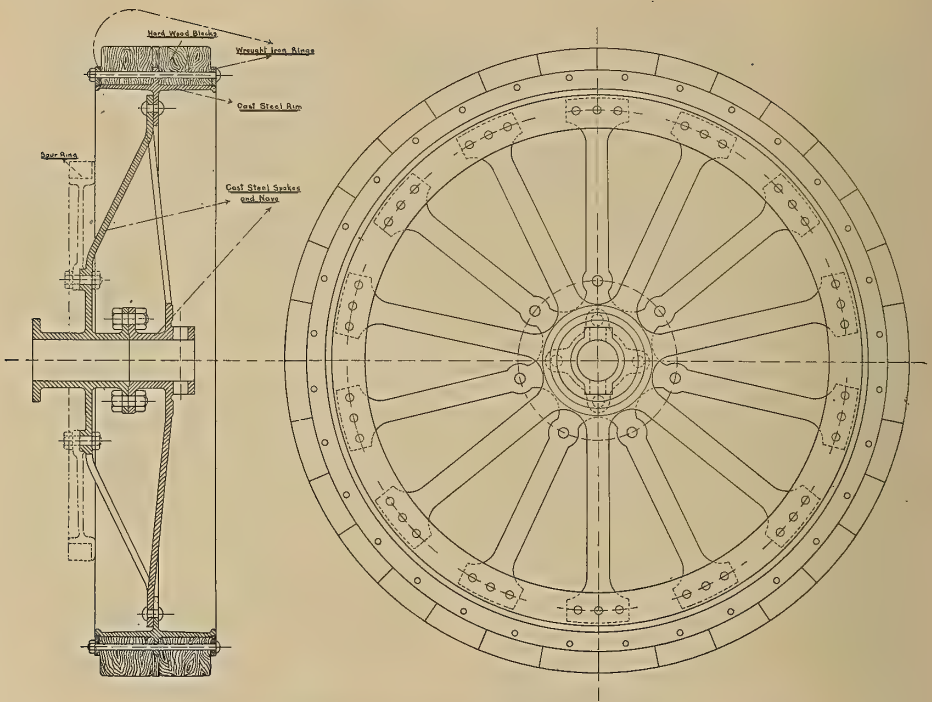
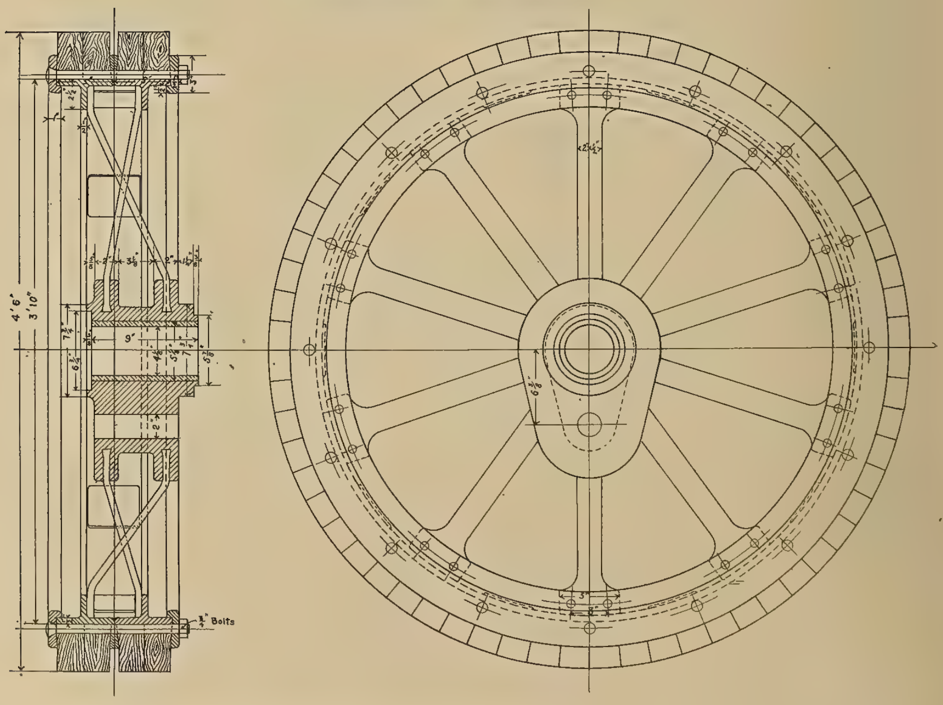


FIG. 12.—CLAYTON & SHUTTLEWORTH STEAM TRACTOR. CROSS SECTION THROUGH GEARING

must be of the slip type. The compensating gear consists of two bevel wheels and three or four pinions arranged as follows: The inside bevel wheel is keyed to the main axle; another bevel wheel is pinned to the driving-wheel boss, which runs loosely on the axle. The three pinions are carried on studs fixed to the compensating plate. The spur ring of the road gear is riveted or bolted to the plate, and not cast together, for obvious reasons. When the engine travels in a straight line the teeth of the bevel pinions act as drives only. The pinions do not revolve on their studs, but drive both the bevel wheels at the same speed. When the engine is required to turn to the right or the left hand, one driving wheel having a tendency to travel faster than the other, the bevel pinions re-



FIGS. 13 AND 14.—WOOD BLOCK TRACTOR DRIVING WHEEL FOR 5-TON TRACTOR.
CHAS. BURRELL & SONS, THETFORD



FIGS. 15 AND 16.—SAVAGE'S TRACTOR. DRIVING WHEEL FITTED WITH HARDWOOD BLOCK TIRE

FIG. 17.—TWO-CYLINDER COMPOUND TRACTOR OF THE OPEN TYPE. JOHN FOWLER & CO.

volve on their pins to allow for this accelerated speed of one wheel. For locking the compensating gear the driving pin must be driven further in, so that the pin enters the centre plate as well as the bevel wheel. It will be seen that when the pin is inserted, the bevel pinions can only then act as drivers. This locking gear is a very important matter on tractors running at higher road speed than ordinary traction engines. When the

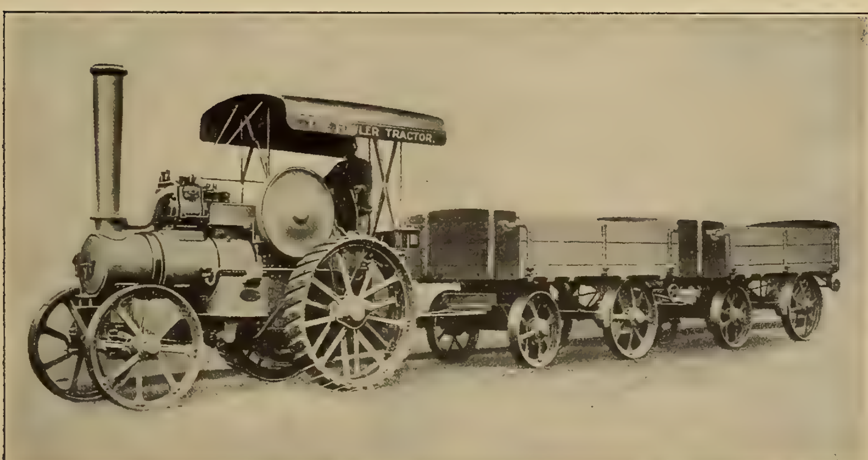


FIG. 18.—MESSRS. FOWLER'S TRACTOR WITH TRAILERS

slow-moving engines require the compensating gear being locked, a man is in attendance to do this; and even while in the act of performing this work, if the engine is on difficult ground, mischief may happen before the work is accomplished. Many accidents have happened with tractors not being locked quickly; the ordinary locking gear appears to be a snare. Messrs. Burrell's locking gear, actuated from the foot plate, is one wheel doing all the work, the other merely spinning round and slipping. On some roads such irregularities spell disaster. More serious still is the want of the locking pin when the engine is coming down a hill with a load behind; the load has more than once forced the engine across the road. The loaded trucks have a tendency to get in advance of the engine, and some accidents have resulted from this. We now come to

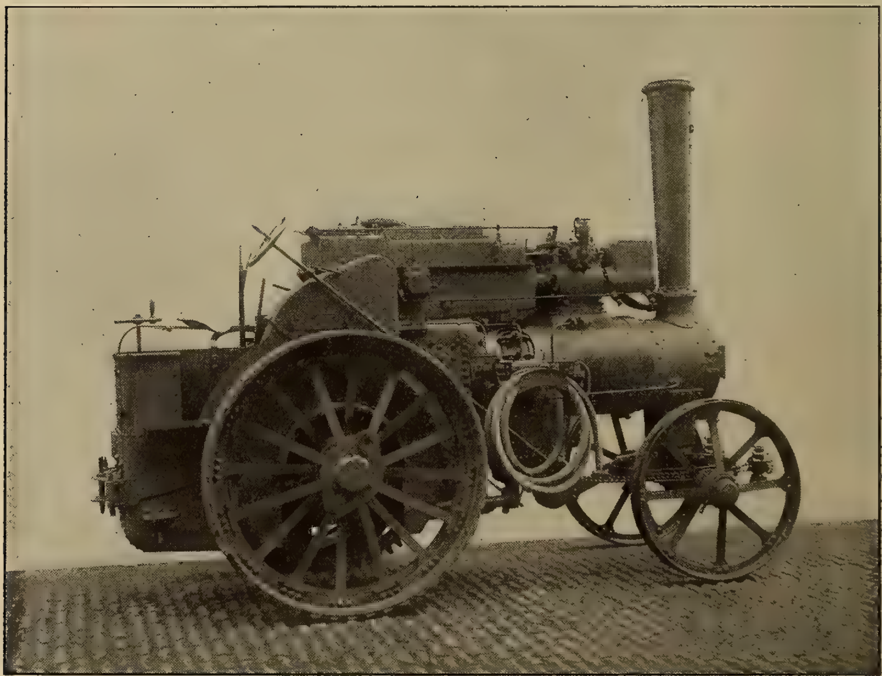


FIG. 19.—THREE-CYLINDER TYPE WITH TANDEM COMPOUND ENGINE

the real remedy (see Fig. 9) which is self-explanatory). It is of some interest to remark that, as far as we know, Messrs. Ruston & Proctor were the first to make the locking gear act by a lever from the foot plate. This was patented Dec. 6, 1876. Messrs. Fowler, as well as Messrs. Burrell, are both able to lock the compensating gear from the foot plate. The locking gear is required when the engine is hauling a load up a hill and the road is slippery— the slip-winding drum combined with the compensating gear. Messrs. Clayton & Shuttleworth's tractor shows this in the cross-section, Fig. 12; the drum is shown riding on the compensating plate; the drum can be released, so that the rope can be paid out while the tractor remains stationary. When it is necessary to haul the load, the pin shown at *A* is allowed to spring into one of the holes provided for it; the driving pins on the drum side must be withdrawn.

The engine can be run for winding; and one advantage of the winding drum being combined with the compensating gear is, the axle remains stationary while the drum is being worked.

Mention may be made of the winding drum carried on an independent stud, and driven from the crankshaft by means of an upright shaft and bevel gear, as adopted by Messrs. Fowler & Co. on their 3-cylinder, compound tractor of the closed type. Fig. 11 illustrates a compound tractor made by Messrs. W. Foster, Ltd., fitted with iron wheels fitted with block tires. This brings us to the subject of the driving wheels. In the tangent wood wheel all the spokes take a share in supporting the weight of the vehicle, and this means a more equal distribution of strain over the whole wheel, instead of its being concentrated in the one spoke immediately under the centre of the axle. Tangent wood wheels reduce the excessive vibration due to rapid traveling over set and hard roads; they also reduce the noise, and the composite treads overcome the slipping difficulties, whether upon greasy sets or upon frozen snow. The combination of the above wheels and treads makes the tractor almost an ideal vehicle for the transport of heavy goods. Messrs. Fowler & Co.'s standard tractor wheels are faced with steel, or iron diagonal cross-bars, with hardwood keys driven between each pair of bars; this gives ample adhesion or grip and minimizes slip. Messrs. Burrell's is an excellent example of what a light-weight wheel should be. The whole of the spokes and the boss are cast in special steel; a wood block tire is employed, in order to build the wheel with the boss and the spoke, as shown in two castings bolted together in the centre. The spoke tee ends are all riveted to the same side of the flange of the tire, as shown in Figs. 13 and 14.

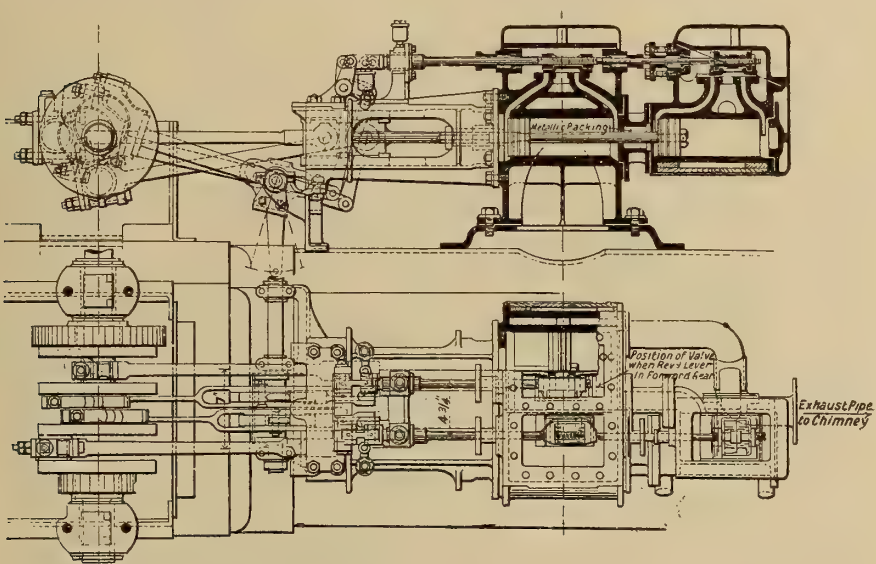


FIG. 20.—ARRANGEMENT OF CYLINDERS OF TRACTOR SHOWN IN FIG. 19

In some instances the wrought-iron wheels are constructed of one wide tee ring, and in others two light tee rings are used; on the double tee-ring type the spokes can be spread further apart at the tire end, thus forming a better wheel. Messrs. Fowler's tractor wheels are formed of two tee

rings. Figs. 15 and 16 represent two views of the "Little Samson" steam tractor driving wheel fitted with a hardwood block tire. The boss of the wheel is made of cast iron, in the usual manner, into which the steel spokes are cast. Two tee irons form the inner tire, held together by a plate riveted between them; wood blocks are held sideways by wrought-iron flanges as shown, with bolts through; the blocks are wedged in the centre, forming a dovetail, which retains the blocks in place.

Fig. 17 represents one of Messrs. Fowler's 2-cylinder, compound, special, spring-mounted tractor of the open type. The open type has two cylinders, instead of three, as in the closed-type engines. The working pressure is 200 pounds per square inch. Instead of having the winding drum on an independent shaft, it is mounted on the axle after the manner of the ordinary traction engines.

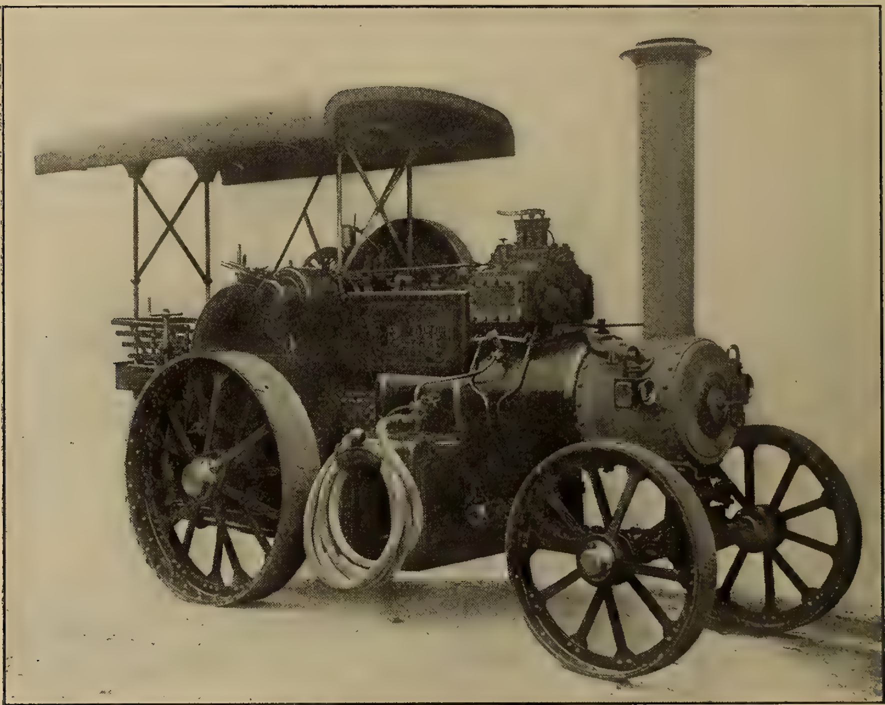


FIG. 21.—FIVE-TON TRACTOR MADE BY MESSRS. GARRET

Fig. 18 shows one of Messrs. Fowler's tractors and two trailers as supplied to His Grace the Duke of Sutherland. It will be seen that the cylinder is mounted on a seat riveted on the boiler barrel. Block brakes are fitted, which act upon both the driving wheels, a shaft for the purpose passing through the tank. The engine is equipped with a neat fore-tank, a disc fly-wheel, an awning and all the usual extras. One tractor only must be hauled on the road. In addition to the 2-cylinder, compound tractor, an illustration of the 3-cylinder type is also presented by Fig. 19. The main feature of interest in this tractor lies in the adoption of a tandem compound engine, with an auxiliary low-pressure cylinder alongside the high-pressure cylinder, the arrangement being clearly shown in Fig. 20. We are told "The object of the arrangement is to increase the ratio of expansion,

and to equalize the power of each crank." Another advantage of the design is: that four blasts per revolution are obtained, causing a more uniform draught through the tubes, a bright fire, and an ample supply of steam. When the full power is required for starting, or emergencies, the two low-pressure cylinders can be worked as in a double-cylinder engine with full boiler pressure. "Under ordinary working conditions the steam is first admitted into the high-pressure cylinder, from which it exhausts into the low-pressure steam chest of the large low-pressure cylinder, which is in communication with the steam chest of the small low-pressure cylinder; thus the steam is divided between the two low-pressure cylinders."* From the engraving, Fig. 20, it will be seen the makers have fitted the tractor with a radial valve gear. All the engine working parts are entirely enclosed in an oil-tight casing; a small pump circulates oil over the bearings and moving details. The driving wheels are faced with steel and wood strips alternately. As already mentioned, the compensating gear can be locked from the foot plate. A supplementary feed-water tank is carried beneath the boiler barrel. The engine is fitted with a steam pump, an injector, and a water lifter with hose pipe.

Messrs. Garret's 5-ton size compound steam tractor is shown by Fig. 21, from which the chief features of the engine can be seen. The cylinders are fitted with outside steam chests; the stop valve and safety valves are arranged at the top. The working steam pressure is 180 pounds per square inch, and the hydraulic test pressure 360 pounds. All the gearing is of the best crucible cast steel, and the teeth of the pinions are shrouded where possible. The whole of the outer gearing is enclosed in sheet-steel casing as shown. An efficient spark catcher is fitted in the smoke-box; the smoke-box is made extra long, to assist the spark arrester. In the smoke-box a super-

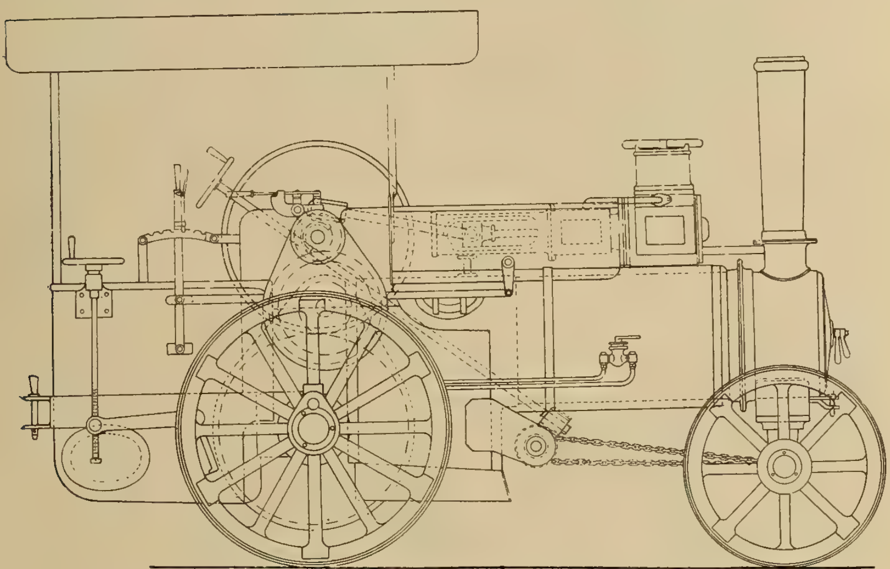


FIG. 22.—SIDE ELEVATION OF GREEN & SON'S TANDEM COMPOUND STEAM TRACTOR

* "The Engineer," Jan. 24, 1908.

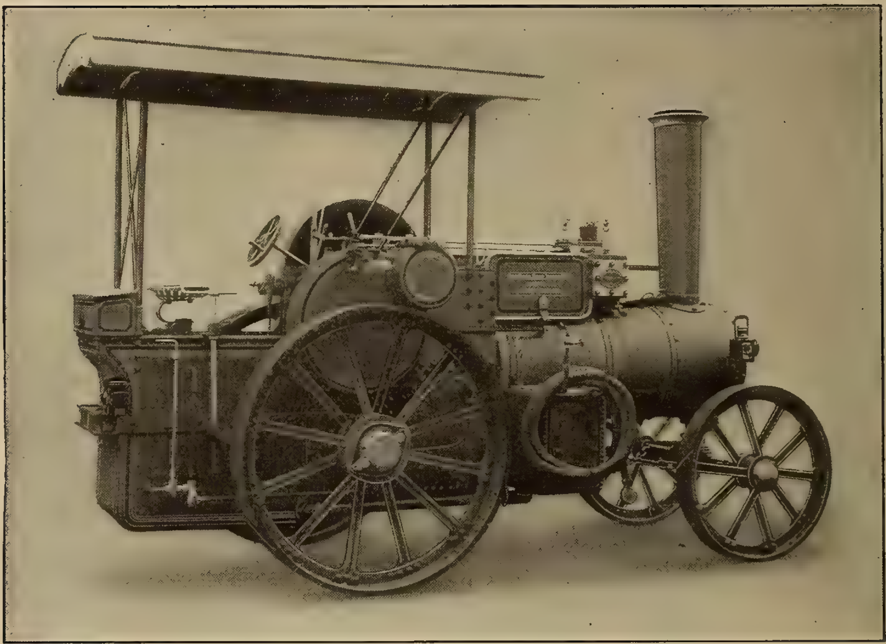


FIG. 23.—STEAM TRACTOR WITH COMPOUND CYLINDERS. RANSOMES, SIMS & JEFFERIES, LTD., IPSWICH

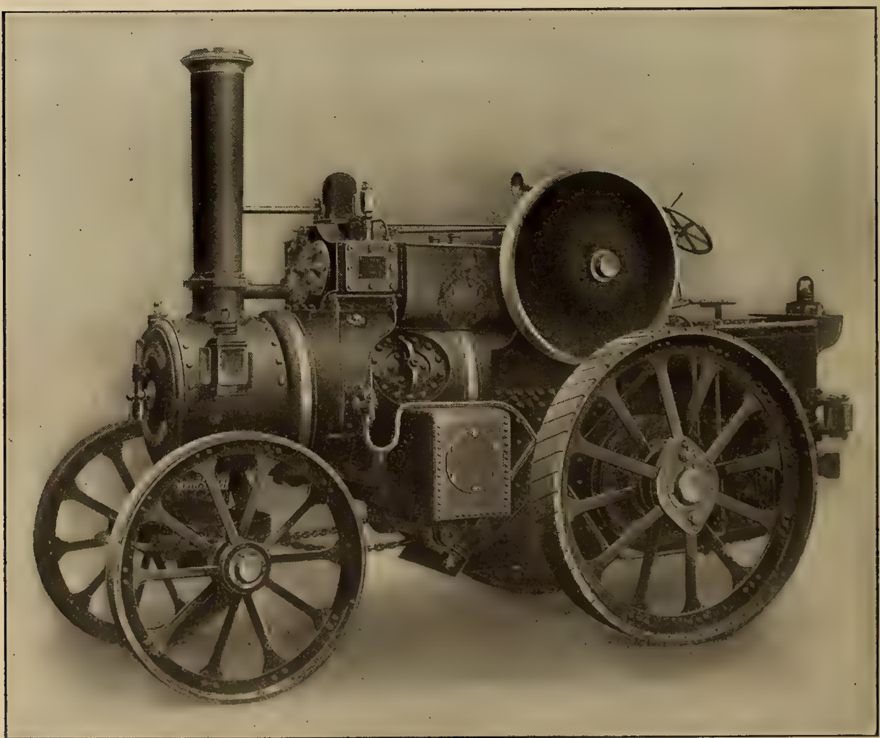


FIG. 24.—ROBEY & CO., LTD., TRACTOR

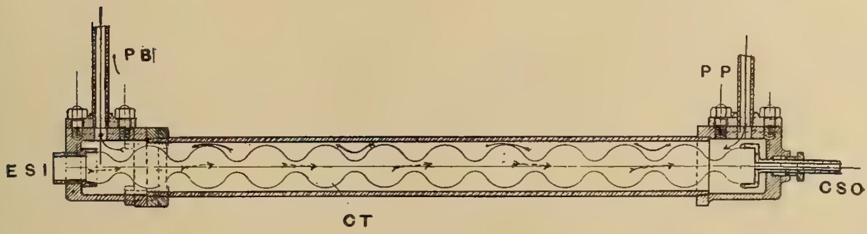


FIG. 25.—THE FOSTER FEED-WATER HEATER

heater for the exhaust steam is arranged among the hottest gases. A wood rack is fitted, and forced lubrication is adopted. To prevent the emission of smoke, a special notched latch is fitted to the fire door.

Fig. 22 illustrates a side elevation of Messrs. Green & Son's tandem compound steam tractor; a section of the cylinder has been shown. In addition to an injector, there is an eccentric-driven plunger pump mounted on the tender. This pump has a double set of check valves, which may be examined and cleaned while the boiler is under steam. The changes of gear give running speeds of 3 and 6 miles an hour, with the engine running at its normal revolutions per minute. Messrs. Robey & Co.'s steam tractor is illustrated by Fig. 24. It is fitted with a compound engine; the cylinders are bolted down to a planed seat riveted to the boiler barrel. The steam chests are arranged on the outside of the cylinder casing, as is usual in other cases now. An extra water tank is mounted beneath the barrel of the boiler; the steerage spindle, with worm and worm wheel, is attached to the underside of the tank. The driving

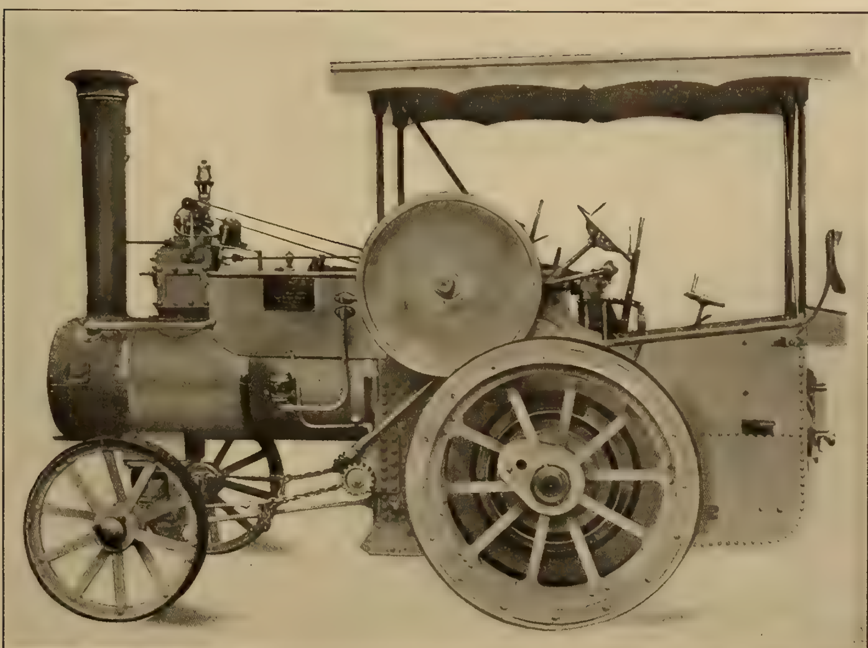
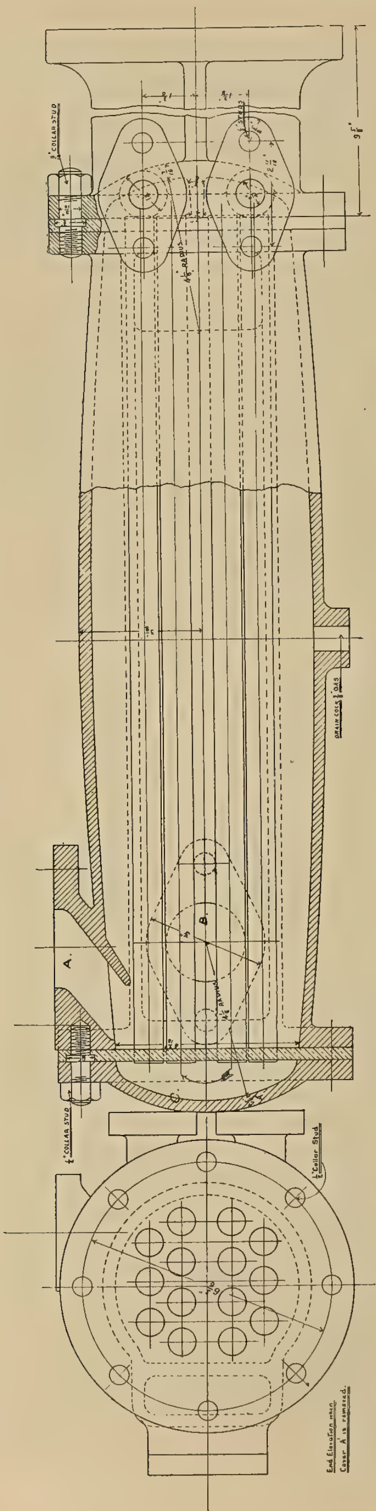


FIG. 26.—TRACTOR FITTED FEED-WATER HEATER. MESSRS. SAVAGE BROS.



FIGS. 27 AND 28.—FEED-WATER HEATER AS USED ON SAVAGE BROS. TRACTOR, SHOWN IN FIG. 26

wheels are of large diameter; the tire is composed of a single tee ring fitted with the usual strips, to comply with the Government regulations. It will be seen that the driving wheels are supplied with two driving pins. The leading wheels appear to be larger in diameter than the general run, but large front wheels are a decided advantage. A cover is provided over the safety valves, and an escape pipe conducts the steam to the chimney. The wire rope is paid out from the top of the drum; the latter is arranged on the fly-wheel of the tractor. A pair of block brakes act on the inner tire of the driving wheels, the spindle passing through a tube in the head water tank.

Messrs. Ransomes, Sims & Jefferies have recently entered into the tractor business. The engine illustrated by Fig. 23 is neatly worked out. It is fitted with compound cylinders, with the steam chests arranged on the outside; balance weights are attached to the square dips of the crankshaft for reducing vibration; the working steam pressure is 180 pounds per square inch, the engine running at 230 revolutions per minute. A continuous-action pump is driven by machine-cut gearing, to reduce the speed; the pump is arranged between the fly-wheel and the horn plate. In addition to the pump, an injector is provided, as shown in the illustration. The combined winding drum and compensating gear are fixed on the fly-wheel side of the engine. Two driving pins are provided on each of the driving wheels. The steerage is arranged with a worm and wheel in the usual manner, except that the diagonal steerage spindle passes through the fore tank, a tube being fitted in the tank to admit of this. Powerful block brakes are provided, acting on the inside of each driving wheel; the lever, screw and hand-wheel for this are shown. Helical springs are used for the hind axle and a plate spring for the front axle.

The hind and front tanks are connected together by means of a pipe near the bottom; all the gearing is well cased in, to prevent the access of dirt on the road. Side plates for screening the working parts from view are included in the outfit, as is also an awning over the foot plate and a tool box. The water lifter and hose pipe are arranged on the front tank. The total weight of the tractor empty is under 5 tons.

Messrs. Foster's compound tractor is fitted with a good feed-water heater, a section of which is illustrated by Fig. 25. It consists of two concentric tubes, the annular space between the two being filled by the feed water at the same pressure as that of the boiler. The inner tube is made from a length of Row's copper-indented tubing, which has a large surface area; a part of the exhaust steam passes through this tube. Cold water is pumped into the end of the heater adjacent to the steam outlet, the water and the steam passing in opposite directions on the counter-flow principle, which gives the highest efficiency. By the time the water has traveled from one end of the heater to the other, its temperature is raised to about 180 degrees F., which enables the boiler to keep up a full head of steam under all conditions. Messrs. Savage Brothers' tractor is represented by Fig. 26. A special feature of their tractor consists of the water heater shown by Figs. 27 and 28. The exhaust enters at *A* and travels to the opposite end of the outer casing, above a diaphragm, and returns among the tubes to the outlet *B*. From the views it will be seen that the water enters at one of the oval flanges beyond the tube plate and travels to the opposite end in the lower tubes and returns through the upper tubes. The lid at one end has a rib fitting up to the tube plate for dividing the flow, while the lid *C*, at the exhaust inlet end, is open as shown, and allows the water to enter from the lower tubes and return by the upper tubes. All the tractors are fitted with springs to the front and hind axles. In some of these cases they are of a very simple type, as shown in Messrs. Green's illustration, Fig. 8. Short spiral springs are applied above the hind axle bracket; the up and down movement of the axle is very slight; the teeth of the third-motion gearing are made of extra length, to take up the movement. This simple form of spring mounting answers well. In Messrs. Clayton & Shuttleworth's tractor, Fig. 12, the spring mounting is on Messrs. Burrell & Son's patented system, which has stood the test of time. On the fly-wheel side the countershaft and main axle brackets are coupled together, so that the up-and-down movement of the axle and countershaft does not affect the gearing, the teeth remaining in pitch. This system of spring-mounting has been largely used for heavy traction engines, and appears to us as being too costly for tractors. Most of the forms of spring mounting have been dealt with by the writer in another place,* making further reference to this part of the subject needless.

* "English and American Traction Engines," London. Longman, Green & Co.

RATE REGULATION OF ELECTRIC POWER

By S. S. Wyer, M. E.

IN 1904 the Columbus City Council, by virtue of the power given all Ohio cities by a then recent Ohio statute, passed an ordinance making 5 cents per kilowatt-hour the maximum allowable charge for electric power in the city of Columbus. The Columbus Railway & Light Company promptly secured a temporary injunction restraining the enforcement of this ordinance. The gist of the whole controversy was whether or not the enforcement of this ordinance would result in depriving the local power company of its property without due process of law, and in taking that property for public use without compensation. The temporary injunction stood until the case was tried on its merits before the United States Court, and was then made permanent, since the city was defeated. Every phase of the cost of electric production was brought forth, and some idea of the volume of the testimony may be obtained from the fact that it occupied 2,537 pages. Both sides secured the services of distinguished engineers and accountants to testify regarding the facts at issue. This covered not only the engineering, but the economic view-points as well. All of this testimony was supposed to be expert; unfortunately, much of it was *ex parte*.

The following is a digest of the case: The court's treatment of the purely local facts would be of no interest, and hence is omitted. However, a clear comprehension of the principles is of fundamental importance not only to the engineer, but to the financier as well.

The present tendency toward governmental regulation of corporations makes a candid and unbiased discussin of the question opportune and eminently fitting. Only United States Supreme Court decisions are cited, on account of the increased weight of their finality. For the sake of brevity, many quotations are condensed and some are paraphrased. The subject logically divides itself into the following: Legal principles, economics of electric power generation, factors determining cost of electric power, fallacies, and conclusions.

The proper co-ordination of the various elements entering into the legal principles is shown in Fig. 1. The fundamental principle affecting the rate regulation of electric power is the same as that affecting the rate regulation of any other public utility. As far as the principle is concerned, it makes no difference whether rate regulation is applied to electric power, water, gas, transportation or storage. The basic idea is that anything that may be classed as a public utility may have a prescribed rate for its sale or use. Since 1876 there have been a large number of United States Supreme Court decisions that clearly establish this basic principle. Therefore, the precedent is clearly defined. Further, no new principle of law is brought out in the question of rate regulation for the sale of electric power. The problem at the best is an engineering one, and the success or failure of any litigation of this sort depends primarily on the ability of the engineers to handle the items under 3E, 3G and 4B of Fig. 1. "When one becomes a member of society, he necessarily parts with some rights and privileges which, as an individual not affected by his relations to others, he might retain.

94 U. S., 124." Electric power generally being a public utility, and hence devoted to public use, the basic principle just given results in the following: "When private property is devoted to public use, it is subject to public regulation. 94 U. S., 130." This does not mean that every electric power plant will be subjected to rate regulation, but only where the power is distributed and sold as a public utility. In the latter case, the electric power company would be enjoying a special privilege, at least to a limited extent, and "the government should prescribe compensation only when it grants a special privilege. 143 U. S., 552."

In practically every case where electric power is sold as a public utility the power company has at least a limited monopoly. "There is no doubt that the general principle is favoured, both in law and justice, that every man may fix what price he pleases upon his own property, or the use of it; but, if for a particular purpose the public have a right to resort to his premises and make use of them, and he have a monopoly in them for that purpose, if he will take the benefit of that monopoly, he must, as an equivalent, perform the duty attached to it upon reasonable terms. 94 U. S., 127." This right of public regulation is operative whether the

FIG. 1.

RATE REGULATION
OF
ELECTRIC POWER

- I *Legislation*
  - 1. *Principle*
    - A *Same as all public utilities*
    - B *Regulation of private property*
    - C *Constitutional protection*
  - 2. *State Interference*
    - A *Power*
      - a - *Inherent*
      - b - *Active*
      - c - *Dormant*
    - B *Limited to*
      - a - *Rates*
      - b - *General needs*
      - c - *Reasonable*
  - 3. *Basis*
    - A *Constitutional rights*
      - a - *Corporation*
      - b - *State*
    - B *Legislation presumed to be constitutional*
    - C *Must be reasonable*
    - D *Obligation*
      - a - *Must serve all*
      - b - *Public has interest in property*
    - E *Property*
      - a - *Fair return*
      - b - *Taken at true value*
      - c - *Adaptability*
    - F *Effect on entire business*
    - G *Each case must be studied by itself*
- II *Relief from oppressive legislation*
  - 4. *Method*
    - A *Allege in good faith that rate is confiscatory*
    - B *Establish cost of power based on*
      - a - *Fixed costs*
      - b - *Running costs*
      - c - *Way power is used*
  - 5. *Work of Courts*
    - A *Jurisdiction in Federal Court*
    - B *Duty*
    - C *Limitations*
      - a - *Pass on reasonableness of rates*
      - b - *Cannot name rate*
    - D *Decision based on returns produced by rates on entire business and true value of property*

FIG. 1.—TABULATION OF ELEMENTS ENTERING INTO LEGAL PRINCIPLES OF RATE REGULATION

company is operating under a franchise or not.

The constitutional protection arises from the last clause of Section 1, Article 14, of the Amendments to the United States Constitution, which reads as follows: "Nor shall any State deprive any person of life, liberty or property without due process of law, nor deny to any person within its jurisdiction equal protection of the laws." This is of the utmost value to a corporation, in that it is a safeguard against rash or unreasonable legislative interference.

The inherent right of the State to regulate public utilities has been recognized for centuries. Its active right is clearly established by precedent. "It is within the power of the government to regulate prices at which water shall be sold by one who enjoys the virtue and monopoly of the sale. 110 U. S., 354." "The controlling fact is the power to regulate it all. The common law, which requires the charge to be reasonable, is itself a regulation as to price. 94 U. S., 133." Absence of local or State laws does not insure immunity from rate regulation. Rate-prescribing legislation may be enacted at any time. In such a case the power will be dormant, but could be exercised by a State at any time, as will be seen from the following: "It is a matter of no importance that the power of regulation now under consideration was not exercised for more than twenty years after the company was organized. A power of government which actually exists is not lost by non-use. 94 U. S., 162."

Some unscrupulous promoters of electric power schemes have emphasized the fact that their prospective scheme was located in a locality in which there were no rate-prescribing laws, and hence offered much stronger inducements for the investment of capital. The absurdity and fallacy of such a statement is obvious from the decision just cited.

The power of the Legislature in fixing rates is clearly defined, and is not unlimited, as has been supposed by some zealous advocates of the people's rights. "The power of the Legislature is exhausted by fixing a maximum rate which will protect the public from the hardships of excessive charges, and an attempt to further regulate is unconstitutional and void." "The Legislature has the power to declare a general law upon the subject of rates beyond which the company cannot go, but within which it is at liberty to conduct its work in such a manner as may seem to it best suited for its prosperity and success. 13 U. S., 691."

State interference is also clearly limited to legislation for the common good of all. "To justify the State in thus interposing its authority in behalf of the public, it must appear, first, that the interests of the public generally as distinguished from those of a particular class require such interference; and second, that the means are reasonably necessary for the accomplishment of the purpose and not unduly oppressive upon individuals. The Legislature may not, under a guise of protecting the public interests, arbitrarily interfere with private business or impose unusual or unnecessary restrictions upon lawful occupations. 152 U. S., 133." "From what has thus been said it is not to be inferred that this power of limitation or regulation is itself without limit. This power to regulate is not a power to destroy, and limitation is not the equivalent of confiscation. 116 U. S., 331." The desirability of conservatism in legislation is clearly indicated in the following: "The forms of law and the machinery of government with all their right and power must, in their actual workings, stop on the hither side of the unnecessary and uncompensating taking or destruction of any private property legally required and legally held. 154 U. S., 399."

The constitutional rights of a corporation in a rate controversy are

clearly defined. "A corporation is a person, within the meaning of the 14th Amendment, declaring that no State shall deprive any person of property without due process of law, nor deny to any person within its jurisdiction equal protection of the laws. 169 U. S., 466." Again, "if the company is deprived of the power of charging reasonable rates for the use of its property and such deprivation takes place in the absence of any investigation by judicial machinery, it is deprived of the lawful use of its property in violation of the Constitution of the United States. 134 U. S., 458."

The constitutional rights of a State have been given. It is obvious as a matter of plain justice between the corporation and the State that the constitutional rights of the former be protected from any unreasonable or unjust acts from representatives of the latter.

The presumption is that all legislation is constitutional. As every statute is presumed to be constitutional, "the courts ought not to declare one to be unconstitutional, unless it is clearly so. If there is doubt, the expressed will of the Legislature should be sustained. 94 U. S., 123." Further, "it should also be remembered that the judiciary ought not to interfere with the collection of rates established under legislative sanction, unless they are plainly and palpably unreasonable." The legislative prescription of rights is *prima facie* evidence of their reasonableness. 174 U. S." These facts make it especially desirable that legislation should proceed with care when enacting rate-prescribing legislation. The fact that their acts are given the benefit of the doubt and that the burden of proof is thrown on the affected party should make legislators weigh the evidence affecting both sides of the problem in a careful and judicial manner.

The fundamental requirement of rate restrictive regulation is that it shall be reasonable and just. "Neither the Legislature nor such commission acting under the authority of the Legislature, can establish arbitrarily and without regard to justice and right a tariff of rates which is so unreasonable as to practically destroy the value of property of persons engaged in business. 134 U. S., 459." "There is a remedy in the courts for relief against legislation establishing a tariff of rates which is so unreasonable as to practically destroy the value of property. 156 U. S., 657." Legislation must also be based on actual facts. Careful investigation of circumstances is a condition precedent to equitable rate regulation. "It is not a matter of guess work, or of arbitrarily fixing all rates. When the Constitution provides for the fixing of rates or compensation, it means reasonable rates and just compensation. 174 U. S., 750."

A public service corporation is placed under peculiar obligations. This fact makes its service conditions more exacting and expensive and would be the case of the private individual. An electric power company, for instance, is under obligations to serve all of its customers. Again, the public has a certain interest in the plant that differentiates it from an ordinary private undertaking. "When, therefore, one devotes his property to use in which the public has an interest, he in effect grants to the public an interest in that use and must submit to be controlled by the public for the common good to the extent of the interest he is thus created. 94 U. S., 125." It is not obligatory on the part of the power company to give the public an interest in its business, but, "if it sees fit to do so, it is only just to declare its obligations if it plans to use its property in this particular manner. 94 U. S., 133."

The value of property affected by rate regulation has an important bearing in determining the equitable

basis. "What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. 169 U. S., 546." It is imperative that the true value of the property be taken as the basis for the cost determination. This may be widely at variance with the amount of money placed in the plant or the capital of the company. "What the company is entitled to demand in order that it may have just compensation is a fair return upon the reasonable value of the property at the time it is being used for the public. The property may have cost more than it ought to have cost, and its outstanding bonds for money borrowed and which went into the plant may be in excess of the real value of the property, so that it can not be said that the amount of such bonds should in every case control the question of rates, although it may be an element in the inquiry as to what is, all the circumstances considered, just both to the company and to the public. 174 U. S., 757." Excessive promotion costs, poor judgment in management or construction and excessive capitalization will not be recognized as conditions necessitating a high rate. "Original costs may have been too great, mistakes of construction, even though honest, may have been made which necessarily enhance the cost; more property may have been acquired than necessary or needful for the purpose intended. 192 U. S., 213." In the light of the preceding, it is obvious that an equitable rate can be based only on the true cost of the property.

The adaptability of the plant will also have an important bearing on the reasonableness of a given rate and should be carefully considered. An excessive rate is not justified because the use of obsolete machinery produces a high operating cost. Within recent years numerous persons have been duped by investing in consolidating power schemes where much of the equipment of the constituent companies was out of date. The fact that these people have been foolish enough to invest their money in hydrated stock combinations does not make it just to compel the public to pay exorbitant rates for power in such cases.

There are no restrictions as to the aggregate profits on the whole business. "The question is, not how much he makes out of his business, but whether or not any particular transaction is an unreasonable exaction for the services rendered. 183 U. S., 95." Nor is it to be expected that the profits of a small customer should be the same as on the large ones. "It by no means follows that the companies are entitled to earn the same percentage of profits upon all classes of freight carried. We do not think it beyond the power of the State Commission to reduce the freight upon a particular article, providing the companies are able to earn a fair proportion on the entire business. 186 U. S., 267." The primary requisite amount is that the total of the profits on the business as a whole shall be reasonable.

There can be no general rules to fit all cases. Nor would a uniform rate for various companies operating under widely different conditions be equitable. The Ohio plan of a general enabling statute permitting each city council to establish rates to suit the local conditions is a good one and complies with the following: "Each case must depend upon its special facts. 164 U. S., 578."

In order to start relief from oppressive legislation, it is only necessary to allege in good faith that the rate in question is confiscatory. The outsome of the case has no bearing on this preliminary step. "Jurisdiction depends upon the allegations of the bill and not upon the facts as it subsequently turned out to be. 166 U. S., 562."

The establishing of the cost of power production is the crucial point of such litigation. As this is of such fundamental importance, it is discussed in detail later on. In showing the cost as applied to various customers, it is necessary to embody the competitive feature of the business, and for this reason it is not necessary to show profits on all the customers.

Since the question of rate regulation involves a constitutional problem, it obviously places it in the jurisdiction of the United States Courts. This is fortunate, in that it removes to a limited extent, at least, the case from local influences and produces conditions which are more favourable for the development of equity and justice.

The duty and power of the courts is clearly established. "There can be no doubt of their power and duty to inquire whether a body of rates prescribed by a Legislature or a commission is unjust and unreasonable and such as to work a practical destruction to rights and property, and if found so to be, to restrain its operation. 154 U. S., 396." "The duty rests upon all courts, Federal and State, when their jurisdiction is properly invoked, to see to it that no right secured by the law of the land is impaired or destroyed by legislation. 169 U. S., 466." "It has also been a part of the judicial function to determine whether the act of one party (whether that party be a single individual, an organized body or the public as a whole) operates to divest the other party of any rights of person or property. 116 U. S., 399." "This court has declared in several cases that there is a remedy in the courts for relief against legislation establishing a tariff of rates which is so unreasonable as to practically destroy the value of property of companies engaged in the business. 156 U. S., 657." The preceding facts show that, in the event of an electric power company being subjected to oppressive rate restrictive legislation, it is a comparatively easy matter to secure a hearing in the courts and have the case tried on its merits.

The power of the courts is rigidly limited to the judicial side of the controversy. "The extent of judicial interference is protection against unreasonable rates. 143 U. S., 334."

The court cannot even say what is a reasonable rate; thus, if a certain rate is declared unconstitutional by the court, it will be necessary for the legislative branch of the State and not the courts to establish the new rate.

In the light of the precedent on the points at issue, the decision respecting the reasonableness of a rate should be based on the effect of this rate on the earnings of the entire business based on the true value of the property.

ECONOMICS OF ELECTRIC POWER GENERATION

Certain economic features have a controlling influence on electric power plant operation. Some of these have been much overrated, while others have been underrated. A correct understanding and proper co-ordination of these is essential to a comprehension of the true method of computing power costs.

The rapid development of the art of electric power generation on account of the numerous inventions that have been evolved in the past has made the useful commercial life of electric machinery unusually limited. The bettering of the quality of electric service has always been an important feature in stimulating inventors in making improvements in the various phases of the art. Electric power plants in the past have also been subjected to more or less risks on account of the progress made in the art, but the development has now reached such a high stage of perfection that we may reasonably expect fewer changes in the future

than we have had in the past. In other words, the art of electric power generation has reached a stability at the present time which it has never possessed before; for this reason a modern, up-to-date plant that is installed at the present time will not become obsolete in the course of a few years, as was the case in the earliest stages of the development of the business. There are probably no more risks now in this line of work than in any other of the well-known lines of engineering endeavor.

The electric power business should not be classed entirely as a manufacturing industry, for the reason that the large element of expense in the electric power plant is what might be termed the investment. Electric power business is the furnishing of service at such time as a customer may want it. A plant must be in readiness to serve any quantity of power at any time, and, in order to be able to serve its customers under such conditions, the capacity of the plant is a factor that has a vital bearing on the cost of the resulting power. The nature of the business is such that the company can generally in no way control the demand made upon its equipment. The consumer has this demand entirely in his power. In brief, an electric power plant cannot manufacture at a uniform rate throughout the day; but the load is a variable one, and thus increases the cost of producing power.

The electric power business is primarily the furnishing of a service and not a commodity. If the output is not sold at the moment it may be generated, it can never be sold, for the reason that there is practically no method of commercial storage. The distinction between rendering a service and manufacturing a commodity is an important one. The commodity may be manufactured at a uniform rate of production and then be placed in storage until it can be sold to advantage. A service must be used at the moment that it is rendered or it will become forever useless. This distinction is important in differentiating the electric power business from ordinary lines of manufacturing. Probably the most important characteristic of the electric power plant is that the service which it is to offer must be delivered instantaneously.

In nearly all cases of electric power generation the requirements for continuity of operation are such that the plant must be operated every hour of the year. This fact makes the labour cost much higher than would be the case in a purely manufacturing plant.

Some of the distinguishing features that have been mentioned were magnified abnormally by the local company, which tried to show that electric power generation was the only business having these peculiarities, which is a perversion of the facts. Even the court was led astray by this fallacious reason when the master, speaking of a water company, said: "They are not required to keep in possession and on hand machinery necessary to manufacture the maximum demand of that commodity instantaneously so that it can be so furnished at any time." At the very time these statements were made the city was operating two direct-service water pumping stations where the conditions were identical with the power company. The pumps in question must be operated continuously and also be ready to speed up so as to fulfill the maximum simultaneous demands of the water customers. The true position was clearly stated by the city's attorney: "The company has made a laboured effort to show that the electric light business is essentially different from all other kinds and classes of business; that idea is quite erroneous. The furnishing of water by the city of Columbus is, in all important particulars, practically exactly like the furnishing of light by the complainant company. We find the peak-load, stand-by charges, the running expenses, the instantaneous delivery and the diversity factor in the furnishing of water the same as in the furnishing of light." Natural

gas pumping stations, district steam or hot water heating plants likewise present identical service conditions with an electric power plant.

customers, the greater will be the diversity factor. The consensus of opinion in this case was that for Columbus the diversity factor was

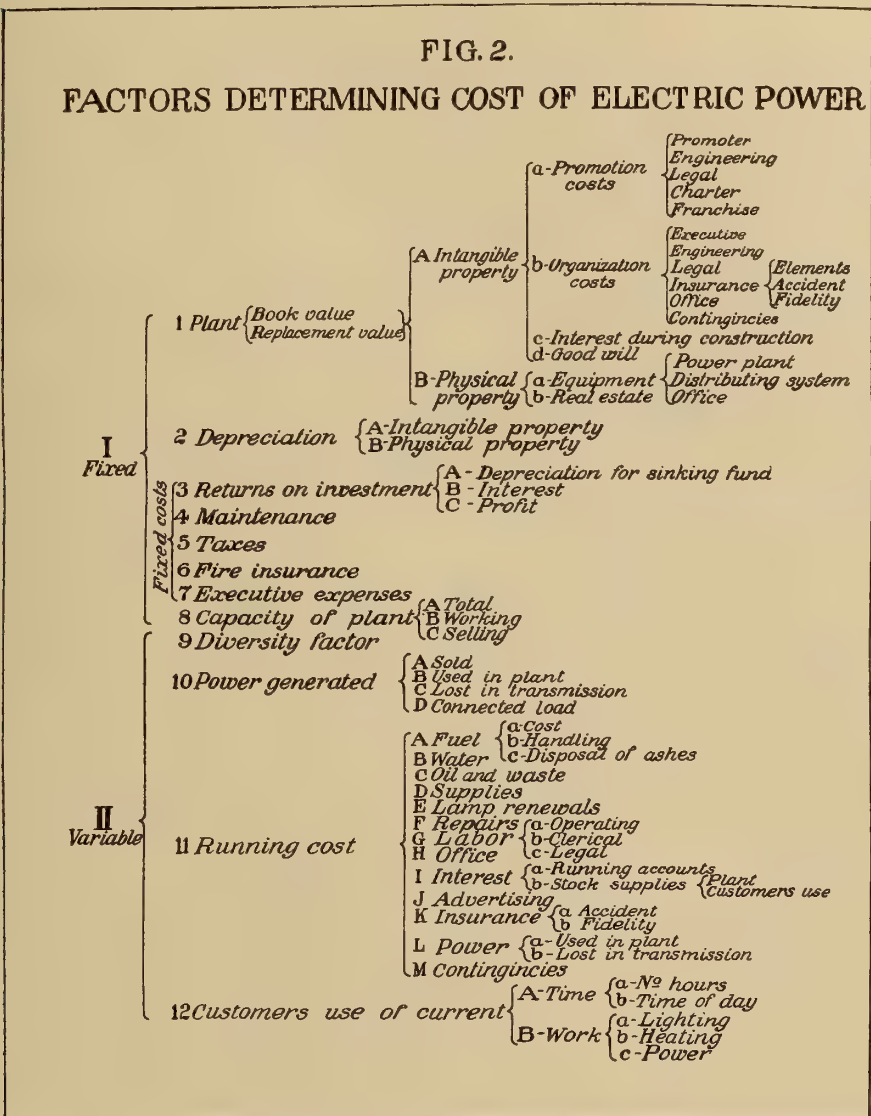


FIG. 2.—TABLE OF COST DETERMINING FACTORS OF ELECTRIC POWER

What is known as the diversity factor is the allowance that is made for the fact that all customers do not use their power at the same time. In general, the larger the number of

1.4. This means that the aggregate capacity—or, what is the same thing, the connected load of the customers—is 1.4 larger than the maximum selling capacity of the plant.

The methods of using money in an electric power scheme are quite different from the average manufacturing enterprise. In the power scheme the major part of the capital is tied up in equipment. This means that the fixed charges on the plant will have the most direct influence in controlling the power cost.

No money is invested in storing a commodity tied up for future delivery, or, in comparison to the investment, very little is invested in supplies, the latter consisting essentially of fuel, oil and waste for the plant and supplies for the customers. The amount of money invested in fuel supply will, of course, depend upon the proximity of the plant to the sources of supply. If this is remote, and there is a probability of interference in delivery, then, in order to secure continuity of operation, a large reserve of fuel supply is necessary. This latter requirement is a strong argument for the location of large electric power stations in the coal fields and the transmission of energy at high tension rather than shipping the coal.

Practically all the power companies' customers should pay their bills every thirty days, and in this way the working capital will be used over and over again in the course of a year. This fact makes it possible to run on a smaller working capital than would be possible in a manufacturing industry for the same investment. This is a feature that gives this business a marked advantage over ordinary manufacturing industries.

The local company operated two separate and distinct plants. This was argued to be of the utmost value in insuring continuity of service in case of accidents to equipment. While this argument seems plausible, it is nevertheless erroneous. One large central station, so arranged that an accident to any one unit would not cripple any of the others, would be preferable to the use of two or more plants in the same territory.

FACTORS DETERMINING COST OF ELECTRIC POWER

A correct determining of the cost of electric power necessitates a detailed analysis and proper co-ordination of all the factors affecting the problem. This is shown graphically in Fig. 2, which explains itself.

The term book value has been used very loosely in the past, which has been largely a question of clerical practice, and it has had no well-defined meaning. One witness referred to it as "anything a bookkeeper chooses to write down." "In some cases, it is an entirely structural expenditure, regardless of any present value. In other cases, it is that amount which will balance with the stocks and bonds issued against the plant. In still other cases, it is a figure which approximates to the present replacement value of the property. Any one of these three cases may be the so-called book value, according to the method of accounting for it."

There is no logic or system in the definitions given or in the use of this term in the past. To avoid ambiguity and to have any comparative value, it must have but one meaning. Referring to Fig. 2, the term book value should include everything under 1 *A* and 1 *B*, except 1 *Ad*, less the total amount set aside for sinking fund up to the time that the book value is reckoned.

There is also considerable laxity in the use of the term replacement value. Five different witnesses give this as follows:

"Cost of duplicating the physical property of to-day."

"The replacement value is the cost of replacing a property of similar character and design of equal physical condition."

"The replacement value means the cost of replacement of the property new to-day with apparatus of the same kind and type as is found in the plant, and in such cases where the property is obsolete—that is, which cannot be purchased in the open mar-

ket to-day—the cost of replacing it with the nearest apparatus that is manufactured to-day."

"The replacement value is the amount required to duplicate the property, allowing for the real estate whatever may be the present value, and allowing for the buildings and equipment whatever it might cost to replace them with buildings and equipment of similar size and type."

"Replacement value is the amount required to replace or duplicate existing equipment, buildings and real estate with equipment of similar sizes and types, new buildings, and, in addition, real estate of the present value."

The first definition is too narrow, in that it is restricted to the physical property only. It would be an impossibility to replace a plant without spending considerable money, which would be classed as intangible property, as shown in Fig. 2. The second and third definitions are the most satisfactory; the fourth and fifth are not satisfactory, for the reason that they take the real estate at its present value. The fallacy of this will be seen from the following: The true value of real estate for power plant purposes may be entirely different from its market value; for instance, one of the Columbus plants is located in the heart of the city, without railroad facilities, and hence is not at all adapted for power-plant work. This same piece of real estate would, however, be of considerable value for other purposes. The factors to be taken into consideration in determining the value of real estate for power-plant work are accessibility for delivery of fuel and removal of ashes, availability of ample water supply, adaptability of ground for building purposes and proximity to centre of electrical distribution. Without these requisites, a piece of real estate is almost valueless for power plant purposes. If the book value has been accurately maintained, there would be practically no need of considering the replacement value.

In determining the replacement value of the given plant, where a prescribed rate is under consideration, it would be necessary to consider the condition of the apparatus and the management of the company during the construction period. If the plant is made up of obsolete, small-sized units, or if the general arrangement of the plant is defective, a high-power cost could not be legally established on the strength of a high replacement value. The only equitable basis would be to establish the power cost from a plant composed of efficient and modern machinery having the same aggregate capacity.

Promotion costs are frequently ignored in discussing this problem. Reasonable promotion costs are legitimate and must be included. "When property is taken by promoters for the purpose of sale to the corporation, whether by purchase, option or agreement, they are bound to disclose any private bargain or secret profits. The laws are very clear in their denunciation of the promoters' secret profits. They are hardly less explicit in their recognition of promoters' rights to profits if secured and taken under proper conditions."* It is perfectly obvious that a corporation will not come into existence of itself; some one must conceive the idea, outline the preliminary plans and bring the matter to a focus. Such work always requires foresight, and many times ability of the highest order. It is therefore but reasonable that proper compensation should be made for such service. Preliminary engineering work and legal counsel are necessary. Charter and franchise costs must also be provided for. Therefore, when the organization proper is made, there should be a detailed statement of every dollar spent in the promotion of the organization.

Just as soon as the permanent

* Conyngton on Corporate Organization, pages 229-231.

organization is completed, it will be necessary to provide for its operation during the construction of the plant. Executive engineering and legal services are absolutely necessary. The engineering services alone may amount to 10 per cent. of the cost. It will also be desirable to carry insurance for the proper protection of the physical property under construction, to provide for compensation in case of injury to employees, and to insure against moral turpitude of trusted employees. Office expenses will also be necessary, and certain contingencies, due to unforeseen difficulties, must be provided for.

There is no reason why the capital invested in a plant during the construction period should not bring in returns to the owners. For this reason, it is only just and equitable that interest be charged on the capital employed during construction. All of the expenses mentioned have gone into something which is intangible, but nevertheless clearly chargeable to the cost of the plant.

In determining the replacement value of a plant that has been in operation for several years, it will be desirable to make some allowances for what may be called the good will or going business of the concern. In a sense, this value increases from year to year. It is an intangible asset and is a gradual growth from the date of organization, and its value depends primarily upon the management of the concern.

The cost of the physical property is a matter of easy determination, and it will be necessary to distinguish between the equipment and real estate costs. The primary factor in determining the cost of power will be the amount of capital invested in the equipment; the sums of the values of the intangible and physical property will, of course, give the true value of the plant, and this will be the amount upon which the fixed charges are to be based.

Depreciation is an allowance that must be made in addition to ordinary repairs and maintenance so that, when the plant or a portion of the plant is actually worn out and must be thrown away, funds shall be available for the replacement of such worn-out parts. There is a sharp distinction between depreciation, maintenance and repairs. "Repairs may be defined as any expense incurred to restore the operative efficiency of the plant, subsequent to or as the result of a break or displacement of the plant, or any part thereof. Maintenance may be concisely defined as repairs in anticipating avoidance or prevention of a break or displacement. "There is also a clear distinction between maintenance and repairs in that the former should be a part of the fixed costs, while the latter comes under running costs. The reason for this distinction is evident from the following: Repairs arise only from the use or abuse of the equipment, while maintenance costs arise whether the equipment is used or not at all. For instance, assume that the plant or a part of the plant should be dismantled for one year. There are certain maintenance costs which will go on regardless of this fact; on the other hand, there would be no repairs due to the wearing out of the equipment.

The salient facts regarding depreciation are as follows: (1) There is an average depreciation. (2) Different classes of equipment have different specific rates of depreciation. (3) Depreciation is properly a part of the operating expenses of the plant. (4) In general, real estate should not be included in depreciation.

We now come to the fixed costs of the plant. These are clearly shown in Fig. 2, in the order of their relative importance. It is necessary to have a clear and correct analysis of each case before a correct determination of power costs can be arrived at. Since depreciation for the sinking fund must be

provided for first, it is obvious that this form of investment is the safest, even if not the most remunerative.

It is self-evident that the selling capacity of the plant is the only portion upon which revenue can be secured. This will always be less than either the working or total capacity. In order to provide for a reserve unit in case of a breakdown, so as not to interfere with the continuity of the service, it is necessary to have some of the equipment out of commission at all times.

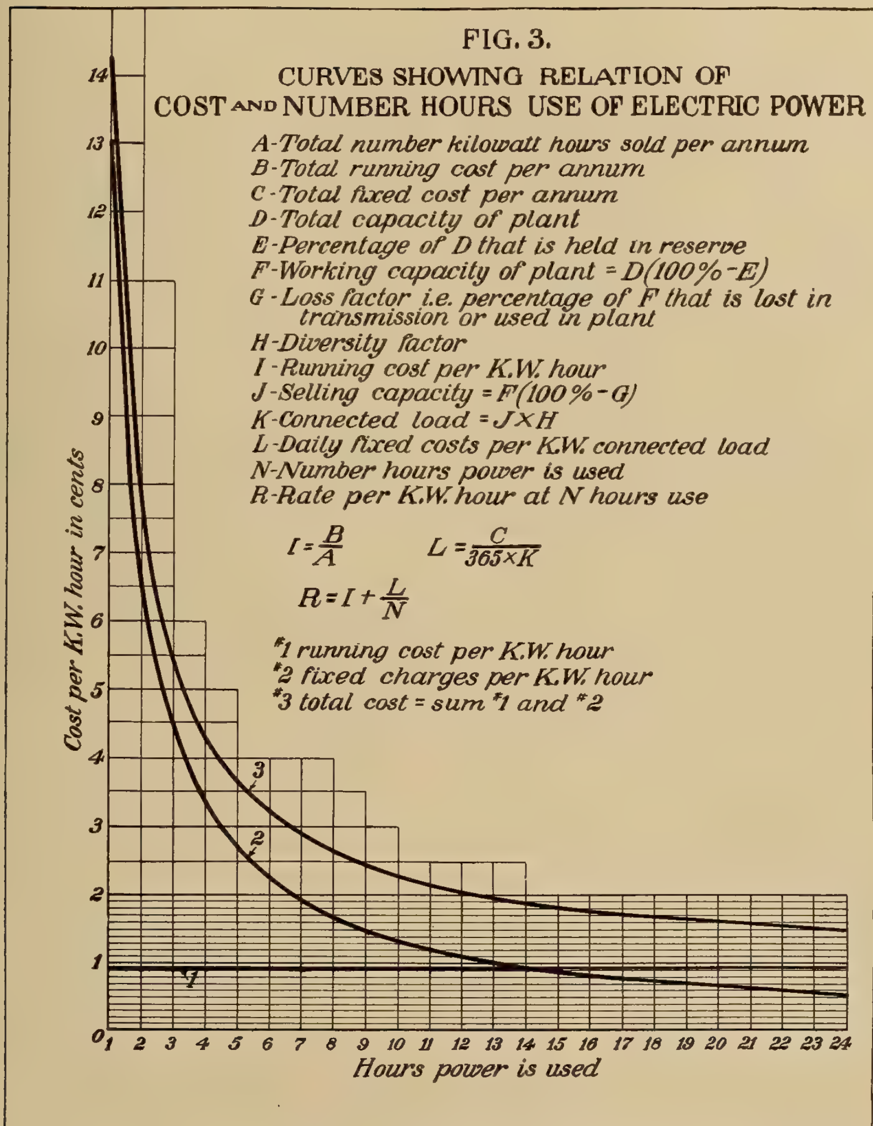


FIG. 3.—CURVE OF COST PER KILOWATT-HOUR IN CENTS AND HOURS POWER IS USED

In steam plants it is possible to secure a high efficiency in the prime mover only by the use of large units. This necessitates a larger amount of

capital in reserve capacity than is necessary where gas engines are used, since the latter give practically the same high thermal efficiency in medium sizes as may be obtained in the larger sizes.

Part of the power generated will be used for operating the auxiliary equipment in the plant. The meters, which register the amount of power actually sold, are usually placed at the delivery end of the transmission lines, and hence do not record the energy lost in transmission.

From the preceding, it is clear that the cost of power at the switch board is not the true cost to the company; the cost of the power sold will invariably be larger than the switch board costs. The power that may be sold with a given equipment plainly depends on the diversity factor. This is always variable to a certain extent and hence comes under the variable factors.

The classification of the power generated is self-evident from 10 ABCD of Fig. 2. The connected load is the product of selling capacity and the diversity factor.

The running costs may be easily determined, if an accurate record is kept of the operations of the plant. It is rather surprising that, in many cases, the cost of handling the fuel and the disposal of ashes are not added to the original fuel cost. A true fuel cost cannot be secured unless this is done.

Lamp renewals in certain cases amount to quite a large item in the course of a year; since this increases the cost of power for lighting purposes, it is desirable to keep this item separate from ordinary supplies. To some it may seem strange to include the legal costs in this division; frequently they have been placed in the fixed costs. However, careful consideration of the problem will convince any one that, in a majority of cases where legal services are required, the extent of these will be practically proportional to the volume of the business, and hence they may be properly classified only as a part of the running costs.

Sometimes power is used to operate electric signs for advertising the business of the power company. If such is the case, it should be charged to advertising expenses, and should not be included in the power used in the plant. In modern power plant construction the tendency is more and more to use electric motors for driving auxiliary equipment, thus resulting in an increased use of power in the plant itself.

The way the customer uses the current has an unusually important bearing on the price that should be received for such service. First in importance is the number of hours that the power is used each day. The curves shown in Fig. 3 were plotted from data representing the power costs of the local company. This forcibly illustrates the high cost of power to the customer using it only a very small fraction of the entire twenty-four hours. The methods of determining the different costs at different times are shown by the data given in Fig. 3. In many cases the time of day would have an important bearing; for instance, if the power company could sell to certain customers who would use the power only during the period of light loading, the power could be sold at a much lower rate than where the customer is permitted to make his demands during the "peak-load" period.

The renewal of incandescent lamps and the taking care of arc lamps is a duty that should be performed by the power company, in order to insure the best service conditions. It is apparent that these charges enhance the costs of power when the current is used for lighting services; that is, the average power company can furnish electric current cheaper for heating or power purposes than they can for lighting purposes. In connection with power service, it will be evident that there would be a large difference as to whether the motors

were running continuously at practically full load, or whether the power consumption fluctuated frequently and through a large range.

The factors shown in 12 *AB* of Fig. 2 make it clear that a flat rate for electric power is not only inequitable, but is not commercially feasible, either from a business or from an engineering point of view. A sliding scale basis is absolutely the only equitable and commercially feasible method of selling electric power; and such a method should take into account the factors given in 12 *AB* of Fig. 2.

FALLACIES

Those brought forward by the city were:

1. Failed to recognize the fact that the corporation had rights, and went ahead and established an arbitrary flat rate, without careful investigation of the facts in the case.
2. Attempting to prove that the art of electric power generation had not changed in the past.
3. Attempting to prove that an average rate should fit all cases.
4. Attempting to show that the renewal of lamps is not a part of operative expenses.

Those brought forward by the power company were:

1. Attempting to show the cost of power without considering the fuel costs.
2. Attempting to prove that obsolete types of machines and methods were efficient and adapted to present use.
3. Attempting to prove that the electric lighting business is entirely different from every other industry.
4. Claiming that profit must be made on all customers. They ignored the competitive feature of business entirely, and would not admit that indirect benefits would come from unprofitable customers.
5. Claiming that plants were highly efficient.
6. Claiming that renewal of lamps should be charged to fixed costs rather than running costs.

CONCLUSIONS

1. Case placed renewed emphasis upon the fact that a sliding-scale basis is the only equitable and feasible method for selling power.
2. Legal interference or prescription of rates must be based on investigation of facts.
3. Cost of electric power is vitally affected by the way a customer uses it.
4. A corporation has the right to earn a reasonable profit on its true investment.
5. Present methods of conducting expert testimony are absurd and of little value in securing justice.

A large proportion of the witnesses on both sides were purely *ex parte*. Some of these, by their own confession in cross-examination, admitted that they were stockholders in property likely to be affected by the decision of this case. The absurdity of having such men testify as disinterested experts is self-evident. The only logical way to handle a case of this sort is to have each side produce *ex parte* witnesses to bring out both sides of the case, and then have one or more absolutely disinterested experts co-operate with the court in digesting and weighing the evidence produced by the two sides in the controversy.

AMERICAN HYDRO-ELECTRIC CONSTRUCTION WORK ABROAD

By H. Lester Hamilton

WHEN Columbus and his doughty sailors braved the dangers and terrors of an unknown ocean in search of new lands to conquer, the Old World stood aghast and marveled at their daring. To-day, American engineers and mechanics, backed by American capital, daily voyage forth to install modern electrical machinery in every habitable part of the globe, carrying with them the spirit of activity and energy which seems to form a natural accompaniment of effort in the New World.

Although the American engineer knows exactly what route he is to follow and how long it will take him to reach his destination, and also has a general idea of what he may expect to find there, the problems that must be solved are even more difficult than those that were encountered and magnified by the superstitious Genoese sailors. There are problems of transportation, problems of labour, problems contingent upon the climate and sanitary conditions of the surrounding country, and a thousand and one other brain-racking problems that fall to the lot of the constructing engineer before he can count his work finished.

The different phases of construction work in connection with the electrical development of water powers in foreign countries are more complicated and tax the ingenuity of those in charge to a greater extent than in any other line of construction work. Conditions are rarely duplicated, each new installation presenting new difficulties that are peculiar to it, and which require for their solution the exercise of good, sound judgment more than anything else.

Among the many great hydro-electric projects that have been developed in various parts of the world, perhaps none is more interesting than that undertaken by the Mexican Light & Power Company. The problem was to install hydro-electric plants on the Necaxa and Tenango Rivers and to transmit the power thus developed to the City of Mexico, which, as is generally known, is situated on a plateau whose altitude is between 7,000 and 8,000 feet above sea level. In this section of the country there is a series of picturesque falls, with vertical drops of 300 to 800 feet and a total fall of 4,500 feet in ten miles.

The development of the Necaxa power is particularly interesting owing to the fact that the sites of the dams and power houses are among the mountains at the edge of the great plateau, in an almost undeveloped country, and more than 100 miles from any base of supplies. It was necessary to build about 30 miles of road over the plain and through the mountains from the Hidalgo Railroad to Necaxa, which constituted in itself a problem involving very difficult and expensive engineering features.

An enormous dam some 180 feet in height and more than 1,200 feet long, was built at the point where the Necaxa River breaks through the mountain range bordering the plateau, the natural shape of the valley being such that an enormous volume of water was impounded. In fact, the Power Company was obliged to buy up three towns that now lie submerged 100 feet beneath the lake formed by the impounded water. Other dams in the tributaries of the

POWER PROPERTY DEVELOPED BY THE MEXICAN LIGHT & POWER CO.

Necaxa River form gigantic storage reservoirs which hold sufficient water to run the power house for months during the dry season.

Over 2,000 workmen were employed in building the new road, driving the tunnels and erecting the dams and power house. The construction of the dams and power house involved the transportation of

some 35,000 tons of machinery, cement and other material over the new road alluded to above. For moving this vast amount of material two traction trains were in constant operation, besides a great number of mule teams and pack animals. The use of the traction trains was undertaken with some doubt as to their economy of operation, but a careful analysis of the charges per ton of freight hauled showed that when the roads were in good condition a material saving was made by their use. Although the grades on the new road were severe, these traction trains often carried loads of 30 to 35 tons per trip.

During the first rainy season, however, the traction engines proved so inefficient and expensive that a narrow-gauge road was built to transport the construction materials. This steam road is remarkable from the fact that only 10 per cent. of it is tangent, many of the curves are of 60-foot radius, and the grade for a considerable portion of the way is 6 per cent.

In the power house there are six impulse water-wheels operating under a head of about 1,300 feet, each wheel being connected to a 5,000-KW., three-phase, 50-cycle, 4,000-volt generator of the revolving-field type. The low-potential current is stepped up to the line voltage of 60,000 volts by five banks of oil-cooled transformers, each bank consisting of three 2,000-KW. units.

The power house is situated at the foot of an enormous cliff some 800 feet high, and from the top of which the machinery and construction materials were lowered in steel cages sliding on great cables. These cages were capable of carrying 15 tons. A temporary electric plant of 1,000 horse-power furnished current for lighting and power and also compressed air for operating the cages and for other construction purposes.

The company early found that it was absolutely necessary to erect fully-equipped machine shops and woodworking plants. Machinery that was liable to need frequent repairs was manufactured as far as possible in these shops, in order that broken parts might be supplied without loss of time or money. Duplicate parts of other machinery were also kept in stock. Foodstuffs were imported in quantity, perishable supplies being preserved in refrigerators by ice of the company's own making.

The uses to which the electricity generated at Necaxa is put are varied and interesting. In the City of Mexico some 20,000 to 30,000 horse-power are utilized for operating cotton mills, flax mills, factories of various sorts, the city's lighting system and an extensive street railway system. In the surrounding country are situated many large mining properties that require several thousand horse-power for their operation. Water power means cheap power, and the Necaxa development has put within the reach of every mine owner power so cheap that he can mine and handle at a profit ores 25 per cent. lower in value than before. It would seem that a prosperous future is thus insured for Mexico's vast mining interests. Another large demand is for pumping purposes, for much of the soil of the great Mexican plateau is fertile and capable of bearing large cereal and other crops, provided it can be properly watered. Former methods of irrigation were as primitive and ineffective as the means employed to grind the grain, but now electricity displaces hand labour, motor-driven pumps irrigate the fields, and electrically-operated mills grind the cereal for the descendants of the Montezumas.

Leaving the high plateau of Mexico we go farther south to Peru, Chili, Brazil, Equador and other Latin-American countries, there to find that nearly all of the machinery used in developing the rich copper, gold and silver mines is American made. And very often this machinery has to be made in very small sections, which can be easily bolted

together after delivery, because the transportation in those far-away countries is mostly by mule back over the steep mountain trails.

Far removed as they are from the great electrical centers of the world, and in spite of the fact that they are lacking in modern transportation facilities, the countries of the southern continent are foremost in installing modern electrical machinery. Many of the small republics possess abundant water powers, but very little natural fuel, and for this reason nearly all the mines, lumber mills, cities, and large towns own extensive electrical plants. As an illustration of the woefully small amount of fuel available, there may be cited the case of the Famatina Development Corporation. For the operation of pumps and hoists in their copper mines the company has had under consideration for some time plans for the erection of a 20-mile transmission line to transmit only 100 horse-power. On first sight, the expense does not seem justified, but the mines are rich, fuel scarce, and ample water power is available.

It is also interesting to note the difficulties that were encountered in transporting an electric-mine hoist and two generators to the Santo Domingo gold mines of the Inca Mining Company, located near Lake Titacaca, in Peru. The machinery was shipped by steamer to the nearest seaport, and from there transported by railroad to the Lake Titicaca region. Here the Inca Mining Company took charge and hauled the machinery 150 miles over roads of its own building to the mines, the first 100 miles of the way being over a wagon road which reached the summit of the Andes at Lake Arracoma, 16,000 feet above sea level. The next 50 miles was only a mule road. To enable the big hoist to be transported over this part of the route it was necessary to build it in sections with no one piece weighing more than 300 pounds, the total weight of the hoist being 13,800 pounds.

Beyond the mine the company built a road about 75 miles long to the Tambopata River, where a little steel-hulled steamboat of American manufacture makes its daily trips

POWER HOUSE OF THE SAO PAULO TRAMWAY LIGHT & POWER COMPANY

laden with a cargo of golden ore. It is needless to say that the steamboat was packed over the mountainous trails in small sections. Even in building the road seemingly insurmountable difficulties were encountered, it being necessary in one place to carry it over a river on a wire suspension bridge 320 feet long.

Leaving the snow-clad heights of the Andes, we find on going eastward to the mountainous part of Brazil a country possessing promising water-power possibilities. In the southern part of this section of Brazil the Sao Paulo Tramway, Light and Power Company has developed over 10,000 horse-power from the Tiete River at a point where it flows through Parnahyba, a village some twenty odd miles from Sao Paulo.

INTERIOR OF POWER HOUSE, SAO PAULO TRAMWAY, LIGHT & POWER CO.

Sao Paulo itself is located upon a plateau 2,500 feet above sea level and about fifty miles from its seaport, Santos, Brazil. The business of the city depends upon the shipments of coffee to Santos, from whose docks some ten million bags of 132 pounds each are exported annually. The country immediately surrounding Sao Paulo is very fertile and produces sugar, cotton and other agricultural products in abundance, while cotton, flour and woolen mills and factories for the manufacture of hats, shoes, brick, coffee, and sugar bags are plentiful. It is thus seen that there is a good market for all the power that can be developed. At the present time the company operates an extensive railway system in Sao Paulo and its suburbs, power also being supplied over the same territory for lighting and industrial power purposes.

The electrical equipment of the power house consists of four 1,000-KW. and three 2,000-KW., 60-cycle generators, direct connected to waterwheels operating under a head of 75 feet; twelve 333-KW. air-blast transformers, stepping up from 2,300 to 25,000 volts, and six 666-KW. and one 2,000-KW. transformers;

three blowers and two 100-KW. exciters, with a suitable switchboard for the control of this apparatus. The power is transmitted over duplicate pole lines 23 miles to Sao Paulo over the company's own right of way. The two lines are about 30 feet apart, each pole carrying two sets of three-phase transmission lines.

The transportation problems encountered in this development were quite serious even from the start. It was necessary to build an entirely new road from the railroad to the power-house site, and the local methods of transportation which were first tried were very discouraging. The only vehicles were carts with solid wooden wheels rigidly fastened to the axle, which turned in wooden bearings. The motive power consisted of several long-horned oxen that persistently refused to exceed a certain leisurely gait that was as fixed as the natural color in the driver's face. The natives claimed that the oxen would not pull the carts if they were greased, as the noise made by the axle as it turned in the wooden bearings was absolutely necessary to urge the animals to their task. They stated also that the friction was an advantage, as it acted as a brake on down grades.

HAULING PLATES FOR FEEDER PIPE. SAO PAULO TRAMWAY, LIGHT & POWER CO.

In regard to the load that the oxen were capable of pulling, for example, it required ten oxen to haul one pole, the weight of which was about 1,500 pounds. The first mules which were used could haul from four to six barrels of cement on a two-wheel cart. The inefficiency of the local transportation methods having been clearly demonstrated in frequent trials, steps were immediately taken to import American wagons. A drove of wild mules was also purchased, and after two months of training were able to haul twenty-four barrels of cement, making the trip in one-half the time that was required previously with the native oxen.

The transformers weighed about five tons each, and in order to haul them over the local roads it was

necessary to use a truck with 12-inch tires, and a special frame or cradle to carry the transformers so that they could not tip over. Fourteen mules were required for each wagon, a round trip being made in one and one-half days. It was found that five tons was the maximum load that could be hauled with one wagon, and some other scheme, therefore, had to be devised for hauling the remainder of the electrical machinery, several pieces of which weighed over ten tons. However, an attempt was made fast. The other cars, loaded with machinery, were then drawn up to the engine. While the machinery was being pulled ahead the track back of the cars was torn up and carried ahead, where it was laid as rapidly as possible. As soon as the last car had been pulled up to the engine the track ahead was again ready for operation. By this means 75 tons were hauled 7 miles in twenty-eight days, while it required three weeks to haul 10 tons the same distance by wagon.

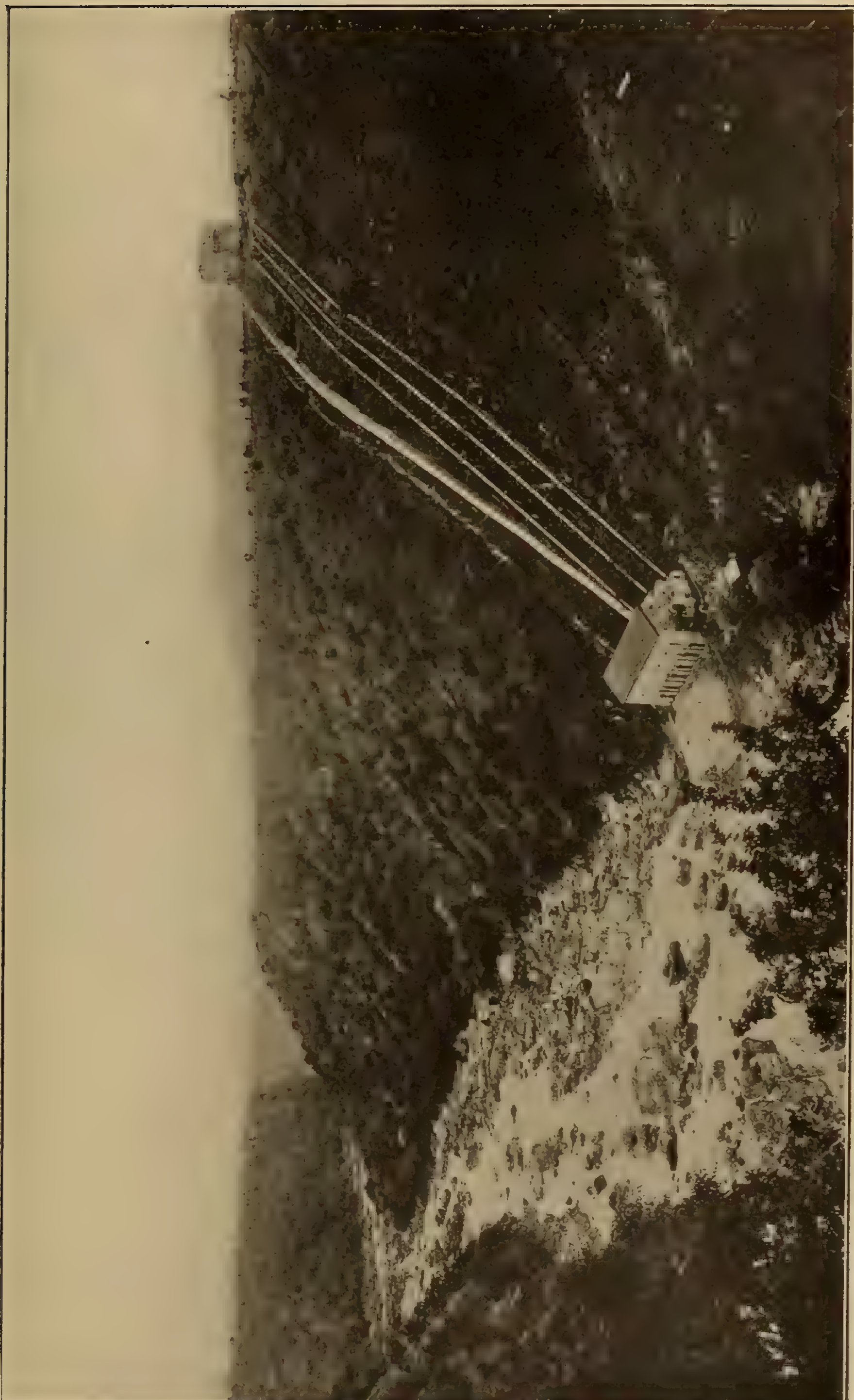
METHOD OF MOVING 75 TONS OF MACHINERY SEVEN MILES IN TWENTY-EIGHT DAYS

made to haul a 10-ton piece of machinery over in a wagon. The trip took three weeks, because for the entire distance it was necessarv to pull the wagon along with heavy block and tackle, aided by animal power.

For the transportation of the heavier material a number of small cars were made and a 1,500-foot section of track arranged to be laid without spikes. One of these cars carried a small hoisting engine, which was run ahead to the end of the 1,500 feet of track, where it was

It is a long step from Brazil to Japan, but in the Flowery Kingdom a hydro-electric project is now being developed that is worthy of consideration. An extensive dam is being built across the Naiko River some 300 miles from Yokohama, it being the intention to transmit the 12,000 horse-power thus developed to the city of Nagoya, 30 miles away, where it will be used by the 350,000 inhabitants for power, light and heat.

American engineers will undertake the difficult work of constructing the



EXTERIOR OF POWER HOUSE, CAUVERY FALLS TRANSMISSION

dam across the Naiko River, which is normally 40 feet deep, but subject to sudden rises of 50 to 70 feet in the rainy seasons. From the nearest railroad all the generating-station apparatus will have to be transported 15 miles over country roads on specially-constructed wagons.

Aside from the transportation and construction difficulties that promise to develop in the installation of this hydro-electric plant, it is of interest to note that this is only one of the many projects that are now under development in Japan, and is an illustration of the fact that American brains and American industries, by introducing American apparatus and methods, are fast becoming prime factors in the modernization of Japan.

In India we find that the cheap power made available by hydro-electric developments has brought about a wonderful change in industrial affairs. High-tension transmission lines, some of them a hundred or more miles in length, connect the generating plants with the distributing centers, where the voltage is reduced for distribution to the silk mills and mines and for lighting and power purposes in the cities. The lighting and fan-motor load alone is said to more than justify the expense of development. This is not strange when we consider that the fan is an absolute necessity in the torrid climate of the low country, and the motor-driven fan has been found to be decidedly more efficient and satisfactory than the hand-operated fan or "punkah," as it is locally termed.

COOLIES HANDLING PENSTOCK PIPES, CAUVERY FALLS TRANSMISSION

One of the largest and most prominent of the electrical developments in India is that at the falls of the Cauvery River, in Southern India. The power developed is transmitted at 30,000 volts to the Kolar Gold Fields, 100 miles distant, where it is used principally for operating quartz crushers and air compressors. It is

interesting to note that the first motor is connected to the line 92 miles from the power house.

At the mines the voltage is stepped down to 23,000 volts, at which potential it is distributed to various parts of the mining district, the distribution circuits alone being over 25 miles in length. Duplicate pole lines are used, and their erection was no easy work, as it was often found necessary to set the poles in solid rock. In some places they were also firmly fixed in iron sockets to protect them from the ravages of the white ants.

In constructing the power house, which was located at the bottom of a deep gorge, it was necessary to build a double-track cableway from the top of the hill to the bottom of the gorge, and on which all of the construction materials and electrical equipment were carried. The cableway was operated on the balanced-car principle, a tank under the car going up being filled with water to counterbalance the weight of the descending car. This was somewhat similar to the methods employed in the Kern River Development in California, where the apparatus and materials had to be lowered down the side of a steep canyon on a steel sled guided by heavy cables.

Transportation methods were also inefficient and unsatisfactory, it being necessary to haul the materials over rough country roads on specially-constructed wagons drawn by elephants and water buffalos. Epidemics of cholera and plague also broke out among the coolie labourers and added to the troubles of those in charge of the construction work. Malaria fever was prevalent in the gorge near the power house, and this necessitated the erection of headquarters for the engineering staff on the top of the hill. The step-up transformer house was also erected at the same point, it being thought advisable to keep as few station operators as possible in the fever zone.

These few brief accounts of hydro-electric developments in foreign lands, while serving to give some idea of the manifold difficulties encountered, do not show a true perspective of the work of the constructing engineer. We must read between the lines to give full credit for his ingenuity, resourcefulness, and masterly management of men and equipment in the face of overwhelming odds.

Even then we who have at our fingers' ends the multiple forces of a modern civilization do not realize the full significance of his work. In the roar of the humming machinery fed with power from harnessed waterfalls, and in the bustle and movement of awakened industrial activity, we must look to find a true appreciation of the American engineer.

PIPING IN STEEL INGOTS

METHODS FOR ITS REDUCTION AND ELIMINATION

By J. F. Springer

SOME substances do not form pipes when cast in ingots. But the steel employed in the manufacture of railroad rails is not one of these. In fact, the increase in carbon, found necessary to produce a rail of sufficient strength and wearing qualities, gives a character to the steel which tends to accentuate the piping evil. So pronounced is the pipe in an ordinary steel-rail ingot that to eliminate it by cutting off the upper end of the ingot would result in reducing to scrap somewhere about 30 per cent. of the whole mass. This is a tremendous loss.

Now it is, no doubt, perfectly true that the piping of steel ingots is not the cause of all the railroad wrecks. At the same time, it can scarcely be contended that it is not a serious contributing factor in most of those which are due to imperfections in the track. This being the case, sooner or later the people will demand that the rail used be a sound one. So it would seem wise that railroads and mills get together and effect some real solution.

It is proposed in the present article to give some account of a number of methods which have been in use or which are proposed by experienced people. Certain of these processes have been thoroughly tried out and are now employed, commercially, with higher grades of steel.

One of the older mechanical processes is that known as the Whitworth system. It is possible that it was in part anticipated by Bessemer. At any rate, the name of Whitworth is the one commonly applied. In this process the ingot is compressed longitudinally by hydraulic means. In the illustration (Fig. 1) *LL* is the mould having steel jackets *KK*. Within the mould are *MM* and *NN* being respectively cast-iron lagging and a sand lining. The whole rests on a carriage or table *C*. This table may be forced upwards by the plunger *B*. *A* is the main compression cylinder. When the liquid steel has been teemed into the mould, the boss *G* is lowered until it comes into contact with the molten metal. The crosshead to which the boss *G* is attached is now secured in an immovable position. Upon operating the press to force the plunger *B* upwards, the metal is compressed. A pressure ultimately reaching six tons, and sometimes as high as twenty tons, per square inch is applied gradually. This may be termed the end compression method. As pointed out by Prof. Howe, it makes its attack in the direction in which the ingot is strongest. The requisite power to effect the compression would be considerable. It seems to be somewhat slow, an ingot of 45 tons requiring upwards of a half-hour or more. The main question, however, is whether it is effective. This method was in use with the firm of Whitworth & Co., and was reported by them as successful. Reports from other sources, however, have not been altogether accordant. That real results of value have been obtained would seem to be indicated by the persistence with which the process has been carried on. Thus, in 1906 one of the largest steel ingots ever cast was compressed by this method. This block of steel weighed upwards of 120 tons, and was cast for the purpose of supplying the stock for the huge turbine

motors for Cunard liners. It is said that a total pressure of 12,000 tons was exerted in effecting the compression. The mould was an enormous box of 180 tons in weight. The ram of the hydraulic press was 6 feet in diameter, its pressure capacity being 3 tons per square inch. It is not likely that a process having no very considerable merit would be persisted in upon a scale of this magnitude.

A second method proposed is that of Mr. James E. York, an experienced steel man. This is a process of rolling—but not of the usual kind. The ordinary longitudinal rolling of ingots is not effective in eliminating piping. The reason for this is probably due to the stiffening of the sides of the steel mass. As it passes between the rolls these comparatively stiff walls take up the major portion of the compression, relieving the softer interior in which lies the pipe. The pipe is reduced in cross-section, but certainly not eliminated. However, Mr. York has designed a rolling mill in which the ingot is passed transversely under the rolls. This is shown in cross-section in Fig. 2. The movable table, or carrier *A*, is mounted on the rollers *BB*, *CC*. The rollers *CC* and the carrier have rack and pinion engagement. The motion of these rollers thus controls the back and forward movement of the carrier. Upon this carrier are mounted six ingots side by side in such manner that they are carried transversely to and fro. The ordinary form of steel-rail ingot is pyramidal. To accommodate this the surface of the carrier slopes sufficiently to enable the upper surfaces of the series of ingots to present an approximately level surface. Arranged longitudinally upon the carrier are ribs or projections immediately below the axes of the ingots. The parallel roll *D* is lowered, and a few passes are made with the view of closing surface blow-holes and partially closing the pipes. The partial closing of the pipes is effected by the longitudinal compression of the ribs. This roll *D* is now withdrawn from service by being raised out of contact with the ingots. The roll *E* is now lowered and thus

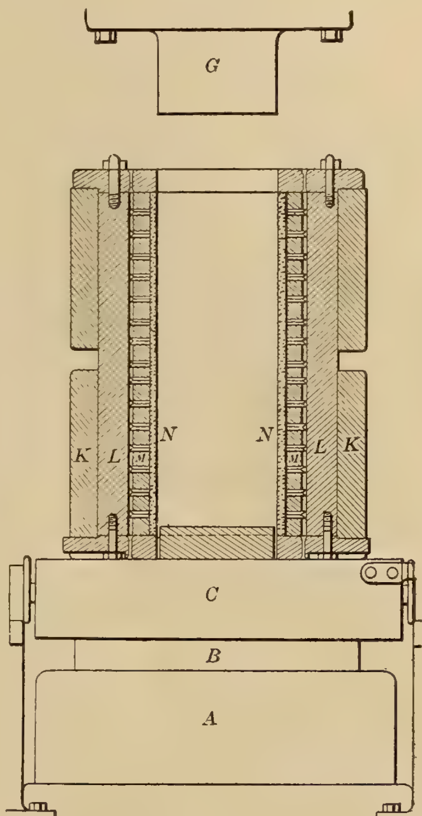


FIG. 1.—WHITWORTH'S HYDRAULIC PRESS FOR THE COMPRESSION OF STEEL INGOTS WHILE SOLIDIFYING.

A, main compression-cylinder; *B*, its plunger; *C*, the carriage on which the mould or flask sits; *G*, boss, against which the steel in the mould is forced; *KK*, steel jackets for the mould; *LL*, the mould proper; *MM*, perforated cast-iron lagging; *NN*, inner sand lining.

brought into action. The form of this roll is quite different from that of *D*. There are longitudinal ribs arranged along its surface at such distances that they will correspond to the axes of the ingots when both move together in making a pass. Now *CC* are driven, and in turn control the carrier. In this way the carrier and

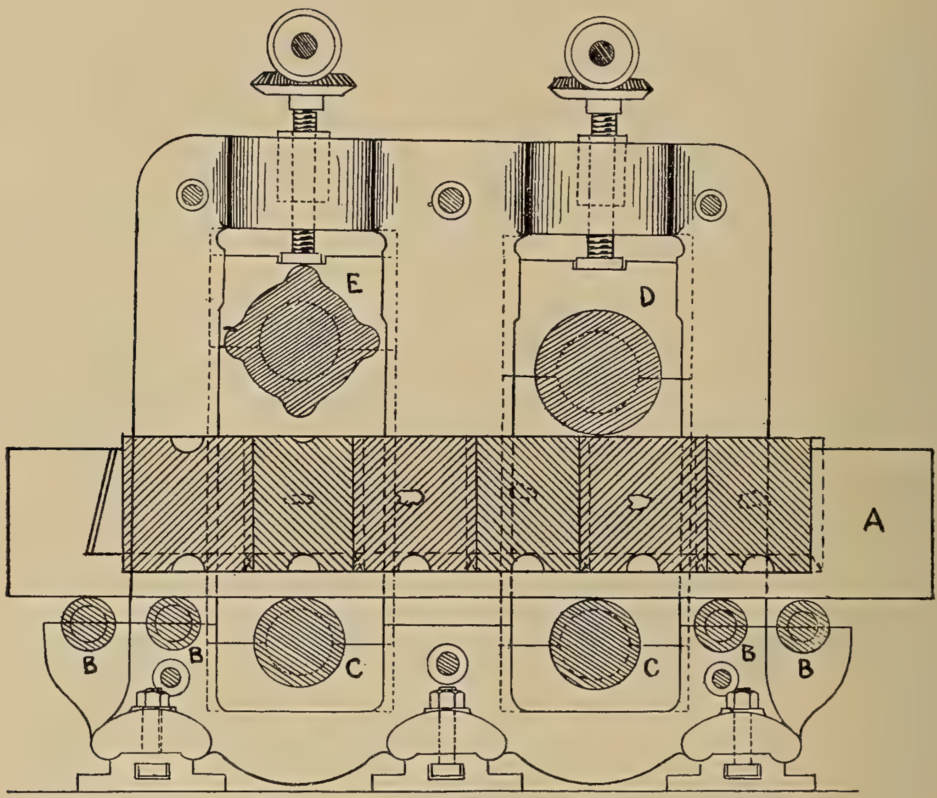


FIG. 2.—THE YORK TRANSVERSE MILL

the roll *E* may be so arranged that, when their connected movements take place, the ribs of the two always correspond in pairs. Suitable mechanism connects *E* in such way that the horizontal speed of the carrier

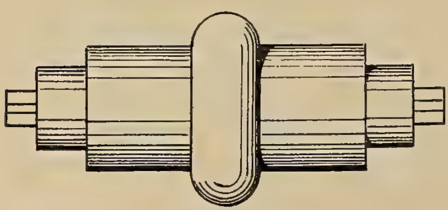


FIG. 3.—TYPE OF ROLLER TO EFFECT CLOSING OF PIPE BY LONGITUDINAL ROLLING

and the peripheral velocity of the roll *E* are the same. Consequently, upon making passes back and forth a second depression will be made along each pipe and vertically above it. In this way the pipes are completely closed. Further, the inclination of the surface of the carrier may be so adjusted to the taper of the ingots that the upper surface formed by the series of ingots is not precisely horizontal, but dips lengthwise the ingots. In this way the closures of the pipes may be effected progressively from the inner end of the pipe in the direction of its mouth. This procedure might be expected, then, not only to close the pipes, but to transfer the "segregates" further in the direction of the small ends of the ingots, or perhaps expel them altogether. It may be added that, if the surface of the carrier be left horizontal, the taper of the ingots will provide a surface inclined in the proper direction.

If the longitudinal depressions seem objectionable, they may be

avoided by casting the ingots with suitable longitudinal ribs, which, when compressed, would leave the surface plane.

sufficient frictional grip upon the ingot, the contact being at first almost *nil*. It is conceivable, however, that the ingot might be forced along, the rolls

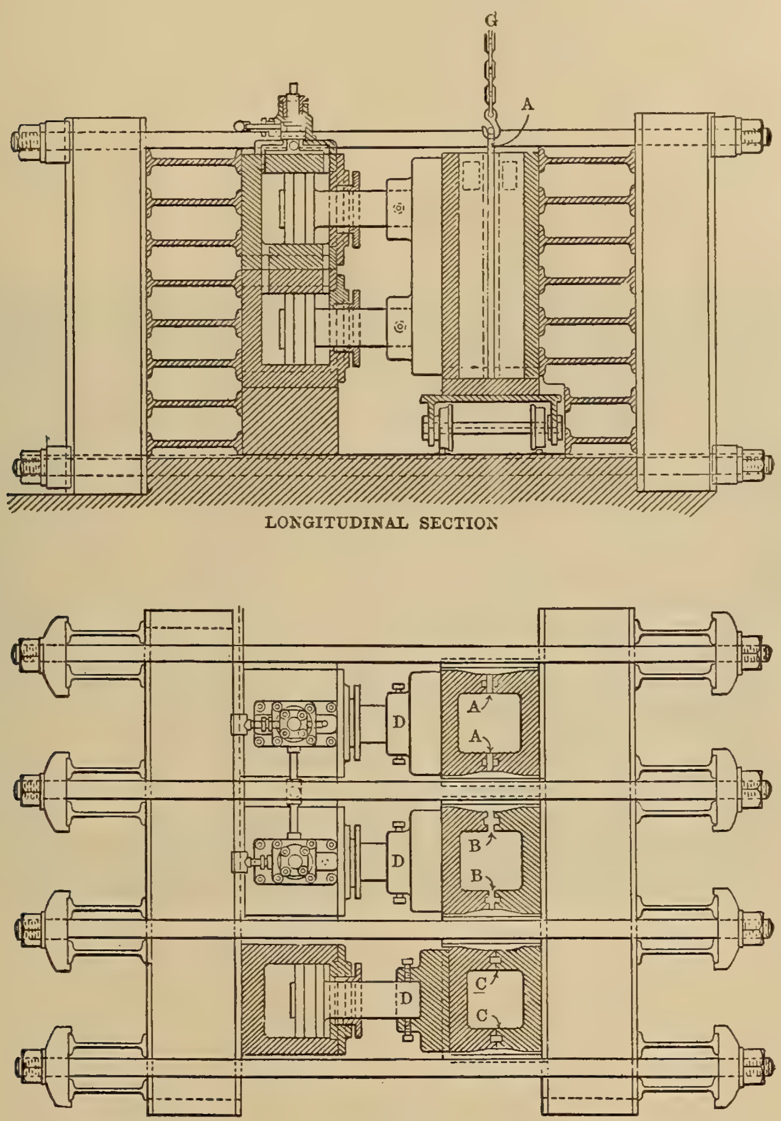


FIG. 4.—ILLINGWORTH CASTING MACHINE FOR LARGE INGOTS IN MOULDS ON WHEELS

It might be thought that the same closure could be effected by longitudinal rolling. Thus let the ribs be formed and arranged as in Fig 3. The difficulty of this arrangement is to get either being driven at the proper rate or left free to be rotated frictionally.

The success of the whole procedure depends upon the question

whether compression by the ribbed roller can be secured before conditions within the pipe have arrived at the point where welding cannot be attained. It is quite possible that, in order to complete the invention to the point of practicability, it may become necessary to provide a means of casting the ingots in position on or very close to the carrier, so that the process may be carried out with sufficient expedition. This process is at present nowhere in use. It seems, however, to be deserving of serious investigation.

At the works of Messrs. Jessop & Sons, Sheffield, England, ingot casting machines have been constructed under the supervision of Messrs. Illingworth & Robinson, which cast ingots of the largest size and absolutely without pipes. This, similarly to the Whitworth and the York processes, is a method of liquid compression.

In Fig. 4 are shown a plan view of the Illingworth machine, and also a longitudinal vertical section. The ingot moulds, say three in number, stand upon a car, which passes upon a suitable track into the interior of the casting machine. Arrived in position here, each mould has to one side a hydraulic press capable of operating horizontally by means of two superposed plungers. The object is to compress the newly made ingots against the framework of the machine. In the plan view cross-sections of the three moulds may be seen. It will be noticed that these moulds are each of a two-piece variety. The uppermost one shows the two halves of the mould separated slightly. Draw-bars lie between the edges, as shown in the engraving. Teeming is done with the mould and draw-bars arranged thus. A crust is permitted to form, whereupon the draw-bars are removed by a hoisting apparatus. At *G* in the longitudinal view may be seen chain and hook

FIG. 5.—FLUID-PRESSED STEEL INGOT COMPARED WITH ORDINARY INGOT NOT COMPRESSED.

attached to a draw-bar and ready for the hoist.

Upon withdrawal of the draw-bars, conditions will be as represented in the middle mould of the plan view. The press is now operated and the ingot compressed transversely, effecting closure of the pipe. It is said that ordinarily fins are not formed at the open places between the halves of the mould. However, if in the case of some special steels such a tendency should develop, the cure is at hand. It is sufficient to make the draw-bars of such shape that longitudinal depressions will be formed in the ingot by projections into the interior of the mould. It is stated also by Mr. N. Lilienberg that the exterior of the ingot is not crushed or folded by the compressing operation.

Fig. 5 (left hand) shows an ingot (in section) as cast by ordinary methods. A 25 per cent. pipe is disclosed in this view. In the same figure (to the right) is shown an ingot cast by the Illingworth liquid compression process. As will be seen, there is entire absence of piping.

Still another method of mechanical elimination of the pipe is one which was tried at the works of Henry Disston & Sons, the well-known manufacturers of saws. This is the Williams process.

By referring to the first view of Fig. 6, a vertical section of an ingot and mould may be seen. This is representative of the moment immediately after casting. It will be observed that the initial form of the ingot possesses an abdominal-like protuberance. As soon as the external shell is sufficiently stiff the one part of the longitudinally split mould is slightly withdrawn from the newly made ingot and a liner *B* (second view, Fig. 6) is introduced, of such size and form as to fill up the abdominal recess in the inner face of the mould. By means of hydraulic pressure the plunger *C* now effects compression upon the ingot—or rather upon the abdominal protuberance—producing in the finished ingot a plane surface (see third view, Fig. 6). The effect of this operation is two-fold. In the first place, it effects closure of the pipe. Secondly, this closure is not simultaneous throughout the length of the pipe, which, of course, occupies the upper portion of the ingot's axis, but proceeds from the bottom up. The effect of this, Prof. Howe thinks, would be to lift the deleterious segregate to a higher position in the ingot. The amount of discard, it is said, was reduced with the Disstons from 30 per cent. of the ingot to 5 per cent. Their experience, however, so far as is known to the writer, was confined to small ingots.

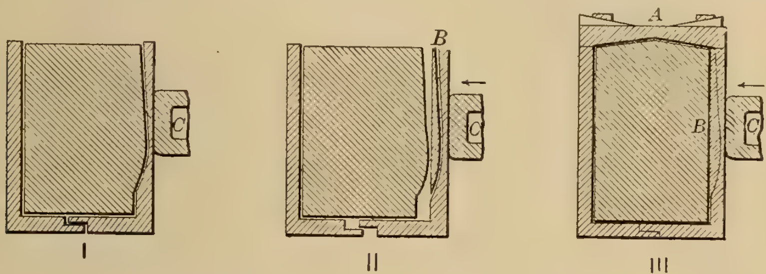


FIG. 6.—S. T. WILLIAMS'S ABDOMINAL LIQUID COMPRESSION FOR SOLIDIFYING STEEL INGOTS

Still another method of mechanical treatment is that known as the Harmet process. This has been in use in Europe for many years. A recent specification of the French Government requires a 28 per cent. discard in the case of ordinary ingots, but accepts a 5 per cent. discard if the

ingot is cast by the Harmet process.

The method pursued in this system is to force an ingot cast in the lower and larger portion of a tapered mould in the direction of the taper. This effects a longitudinal flow of metal and a transverse compression. The pipe is thus eliminated or—perhaps it would be more accurate to say—is not allowed to form. Prof. Howe points out that compression is equal throughout the length of the ingot, and so we could not expect the segregate to be lifted into a pipe which is nowhere permitted to form.

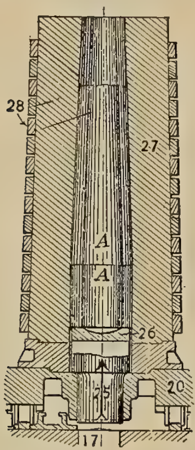


FIG. 7.—HARMET'S LIQUID COMPRESSION BY WIRE-DRAWING

The ingot *AA* is cast in strong, conical mould, 27, reinforced with hoops, 28. Strong pressure at the base of the ingot, 26, forces it lengthwise of the mould, thus compressing it radially.

In Fig. 7 *AA* represents the ingot, which in this case is mainly conical. The mould must be of great strength to resist the tremendous lateral strains, and is therefore reinforced by hoops. The ingot car contains a movable plug, 26, and when in position this is immediately under the mould. Hydraulic pressure is exerted at the base of the movable plug by the plunger, 17, operating upwards. The head of this plunger is rounded, in order to avoid forcing the movable plug out of its proper alignment. Full pressure is not at once applied, the maximum not being utilized until the operation is nearly complete.

The length of time during which the solidifying ingot is subjected to compression varies greatly. Thus, a small ingot of 120 kg. is under compression for about eight or ten minutes, according to the practice at St. Etienne, France. A large ingot (16¾ tons) purchased by the United States was compressed for more than five hours. This was in the Oberbilker Steel Works at Düsseldorf, Germany.

FIG. 8.—SECTION OF AN INGOT, SHOWING EFFECT OF DELAY IN COMPRESSION

A point which is made a great deal of in connection with this system is the ability to begin compression at once, without waiting for a more or less stiff crust to form. In fact, M. Beutter, chief engineer at

the Fonderies, Forges et Acieries de St. Etienne, states that, in the case of certain hard steels, it is "practicable and advisable" to begin compression while casting is still in process. With them an ingot is rejected if compression has been delayed. Fig. 8 is a longitudinal view of an ingot cast at St. Etienne, and with which compression was delayed somewhat. M. Beutter states that, although the section appeared sound at first, upon treatment with acid the form of a filled pipe was brought out and an upward axial flow of the metal disclosed.

One of the claims made for this system may be mentioned here. In the first place, the effectuation of the process requires constant contact between ingot and mould. As the latter is necessarily of large size and weight, this results in an acceleration of the cooling process, especially at the top, where the ingot is smaller and the mould cooler. In consequence of this more rapid cooling of the upper portion of the ingot, it is thought that segregation is, in part, prevented.

This wire-drawing process is interesting. Moreover, it seems to have been rather widely employed in Europe. In addition to the French and German works already referred to, the system has been put in operation in steel works in England and Scotland, and probably elsewhere. Apart from any other considerations, a present disadvantage consists in the length of time involved, and also in the want of simplicity in the mechanical accesssories. But this is a proper field for the exercise of inventive ability by the steel-rail corporations, providing, of course, that wire-drawing is capable of producing a sound mild-steel ingot of suitable size for commercial rolling.

The processes so far described refer to mechanical methods for the elimination of pipes. But this is not the only mode of procedure by which attack has been made upon this problem. The pipe-forming tendency begins, no doubt, from below. The fact that the upper portion of the interior remains liquid longer and that the influence of gravitation is always present, combine to counteract this tendency. Consequently, the pipe is fully formed only towards the top of the ingot. The thermal processes for the elimination of the pipe derive whatever successes they have achieved from a heightening of the former of these corrective fac-

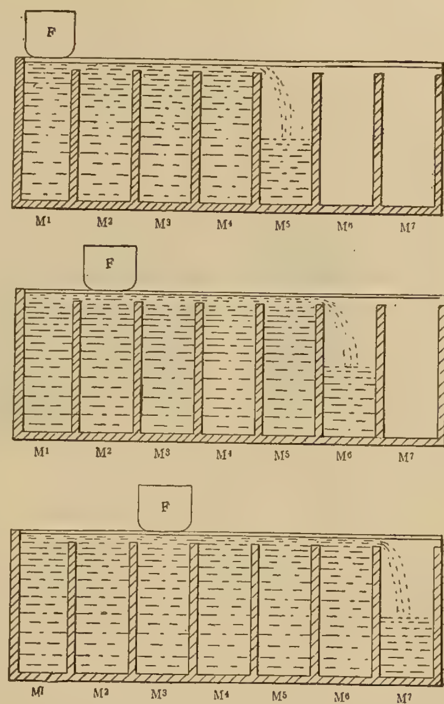


FIG. 9.—PROF. SAUVEUR'S OVERFLOW PROCESS FOR CASTING INGOTS

tors. They all maintain liquid conditions above while permitting solidifying conditions below. That is to say, freezing is compelled to proceed from below. The effect of this is to enable gravitation to fill in the pipe progressively.

Let us begin with Prof. Sauveur's overflow process. In this there is no machinery required. It is necessary, however, to have the moulds of a special form suited to require-

ments of the method. In Fig. 9 we have three sectional views representing each the same series of moulds, but at different stages of the teeming. It will be seen that all the moulds are intercommunicating, the separating walls falling short of the full height. At the beginning of the operation the molten steel is teemed into the first mould M^1 (uppermost view) by means of the special pouring apparatus F, to be described later. This is continued, not only until the steel rises to the top of the separating wall, but until the next mould M^2 and the next, and so on, say, M^5, until all these have filled, each from the overflow from the preceding. That is to say, the teeming for these five moulds is continued from the one position of F until all are filled. This is the first operation. Let us stop at this point for a moment and see what has been accomplished. There has been maintained during the whole procedure a supply of molten metal at the top of M^1. For a considerable time, then, the ingot solidifying in this mould has had its upper portion kept at a high temperature and has had available a supply of liquid metal. These conditions are favourable to the elimination of the pipe as it forms. What has been said of M^1 may likewise be said of M^2, except that the period was reduced. And so on with the remainder. It should be observed that the last mould M^5 was under merely the ordinary conditions of the usual practice.

Now Prof. Sauveur, as far back as five or six years ago, experimented repeatedly with this procedure, obtaining similar results each time. It will suffice, then, to give the results of one experiment. The metal was crucible steel. This was cast in a series of six ingots. Each ingot was 3½ × 5½ × 22½ inches in size, and weighed 100 pounds or more. The average length of pipe when the casting was done by the ordinary method was about 8 inches. That is to say, the upper portion to the extent of about 35 per cent. was seriously damaged at the centre. In Fig. 10 are shown the upper portions of the first five ingots. The first two of these had absolutely no pipe. The next two disclosed very small pipes of about 1 inch in length. The fifth ingot had a pipe of four inches—a reduction of 50 per cent. The head of the sixth ingot is not shown. It was not to be expected, as already pointed out, that the final ingot should disclose any reduction in the pipe.

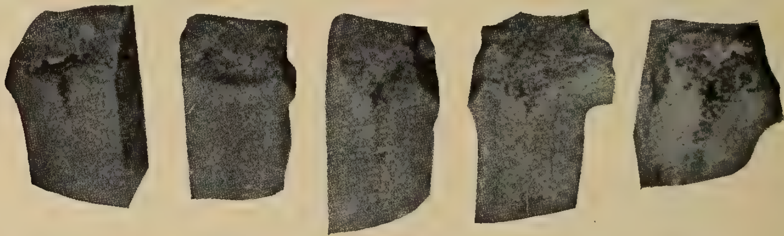


FIG. 10.—UPPER PORTIONS OF FIRST FIVE INGOTS CAST BY PROF. SAUVEUR'S METHOD

Returning now to Fig. 9, second view, we are ready for the extension of the first operation, which had the effect of totally curing the first two ingots. Having finished the teeming to the point of filling, say, five moulds, the pouring apparatus is now advanced to the second position at the top of the mould M^2. When M^6 is filled from this position, by means of the overflow from mould to mould, the teeming pot may be advanced to the next position—over M^3, third view of the figure. By means of such a pro-

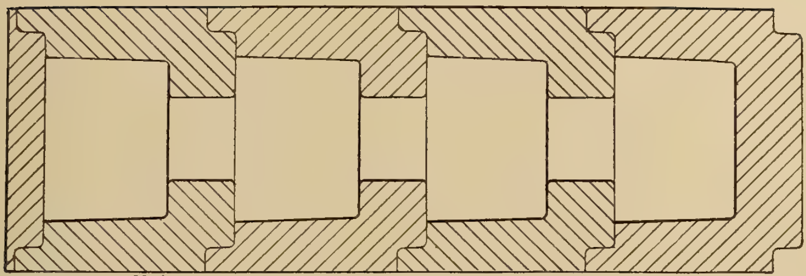


FIG. 11.—SECTION OF A CONTINUOUS FORM OF MOULD

cedure all the ingots, except the final two or three, may be cast without pipes.

Now, of course, the number of moulds that will have to be filled by the first operation, before shifting the apparatus F to its next position, will depend upon the metal, the size and form of the ingots, and so on. But these matters may readily be settled by suitable experiments.

The form of continuous mould shown in horizontal section in Fig. 11 has been devised as applicable to this procedure. Of course, the connection between ingots is only deep enough to secure good results. In Prof. Sauveur's experiments, it was found necessary to shape the connections between the moulds in such way as to prevent the splashing of metal against the opposite sides.

A special teeming apparatus was devised in order to prevent the excessive disturbance which would have arisen had the pouring been direct. This is represented in section in Fig. 12. The bottom of the pot or crucible is perforated at H. There is a false bottom, also perforated, shown at G. The metal is first poured into the vessel at F. Thence it passes through the false bottom, by way of the rather small perforation f, into the lower compartment C^2. The relative sizes of the perforations f and H are so adjusted that C^2 is continually drained of metal.

In a letter to the present writer, Prof. Sauveur says: "Some experiments were conducted in casting large ingots of steel containing some .70 per cent. carbon; but while the results obtained were quite satisfactory, the experiments were discontinued before the full value of the overflow process applied to large ingots had been demonstrated."

This system would seem to deserve the attention of the rail mills. It is quite possible that more or less modification would have to be made in the details. It may be said that it is not a commercial method. That may very well be. But patience, de-

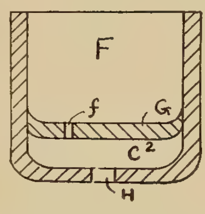


FIG. 12.—RECEPTACLE HAVING A FALSE BOTTOM, DEVISED TO AVOID EXCESSIVE DISTURBANCE OF THE METAL WHEN TEEMING

termination and brains are the factors which have aforetime frequently succeeded in transforming the non-commercial into an economic success.

Another method of procedure is to cast the ingots with the large end up. In accordance with present practice, ingots are cast with the large end down. There is no question but that this method permits of economical procedure at the mills. Thus, in accordance with Wood's system, the cars carrying moulds are run into position for casting. The moulds having been filled, it is not

necessary to wait until the ingots have solidified. On the contrary, the cars are promptly run into a position alongside the soaking pits. On the other side of this train of cars is another, upon which are arranged the lower parts of moulds. When now the train, loaded with ingots solidifying in their moulds, arrives between the soaking pits and the empty train, the moulds are lifted off from the hot ingots and deposited upon the mould bases carried by the train alongside. The ingots may then be lifted off and placed in the soaking pits. All this is advisable from the point of view of economy of procedure. Its success depends

FIG. 13.—INGOTS OF METALLIC ZINC

upon the possibility of stripping the ingots as they stand in the cars. This, in turn, is facilitated by the form of the ingots—truncated pyramids, with the large end down. It will be seen that the taper of such ingots readily lends itself to the easy withdrawal of the mould.

But why should it make any especial difference whether an ingot is cast big end up or big end down? It has been found, however, that it does make considerable difference. In Fig. 13 are shown views of two split ingots. These were of zinc. In casting, the one was formed with the big end up, the other with the big end down. It will be seen that the difference in piping is very considerable.

Profs. Howe and Stoughton performed a series of interesting experiments in ingot casting, using wax for their material. Two ingots were

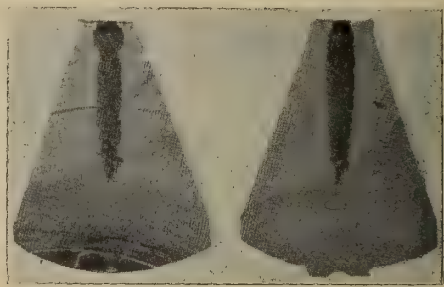


FIG. 14.—SHOWING EFFECT OF TOP-POURING AND BOTTOM-POURING ON DEPTH OF PIPE

cast, differing only in the one having its large end up, while the other was reversed. The piping in the one with the big end up was 30 per cent. of the length, while its companion disclosed a pipe occupying 82 per cent.

Mr. A. A. Stevenson finds that casting with the large end up has a distinct influence upon the length of the pipe. Thus, Figs. 14 and 15 represent ingots cast in the two ways. They were not all of the same heat, but the analyses were approximately identical. The first ingot of Fig. 14 was teemed from the top, the other

FIG. 15.—DEPTH OF PIPE DECREASED BY CASTING WITH LARGE END UP

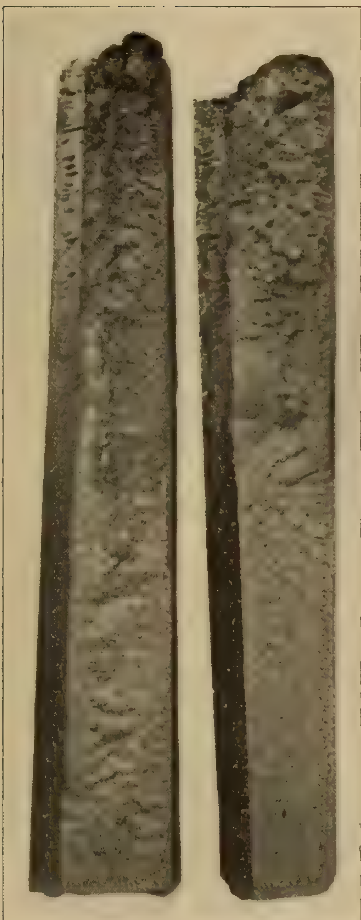


FIG. 16.—TWO INGOTS CAST, ONE WITH THE BIG END AT THE BOTTOM, AND THE OTHER WITH THE BIG END AT THE TOP

The ingot cast with the big end down disclosed a pipe—not traceable throughout its whole extent in the figure—occupying 75 per cent. of the length of the ingot. The ingot cast with the big end up has but a very small pipe. These ingots were of good size, being 8¾ inches square at one end and 6¾ inches square at the other and 4½ feet long. In another test, the piping of the two ingots was 21 per cent. in the case of the one cast with the big end up, as

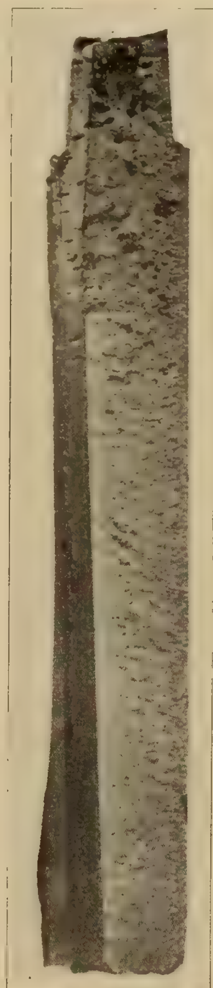


FIG. 17.—INGOT CAST WITH A SINKING HEAD, AND A FIREBRICK SLEEVE AROUND THE CONTRACTED PART AT ITS TOP

from the bottom. This difference in pouring appears to have had no effect on the pipe. But the effect of reversing the mould (Fig. 15) is striking.

Mr. J. O. E. Trotz is reported by Prof. Howe as having reached the same conclusion as to the effectiveness of casting with the large end up. In Fig. 16 are shown the ingots. These were cast from the same ladle at the same time, the steel being of 50 per cent. carbon. The only difference between the two was in the position of the mould.

against 73 per cent. with the one cast under reversed conditions.

As to why this method of casting should yield such pronounced results, it may be sufficient to call attention to the fact that every successive horizontal layer in an ingot cast with the big end up is larger than the one below it. It therefore cools at its centre more slowly. This compels axial solidification from below. Consequently, gravitation has opportunity to fill in the forming pipe with softer liquid from above. It

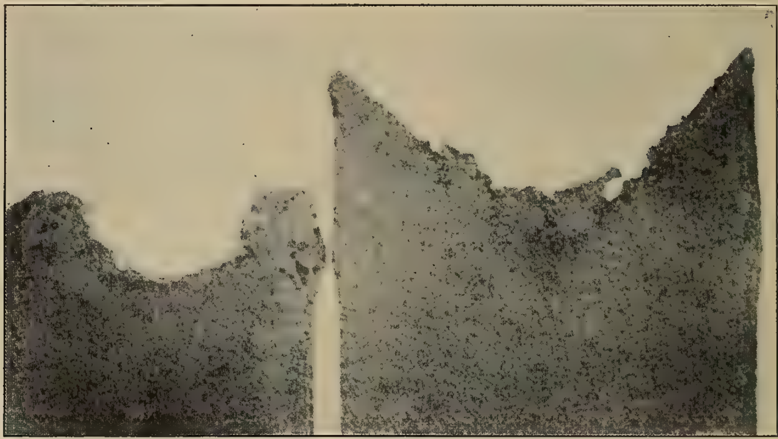
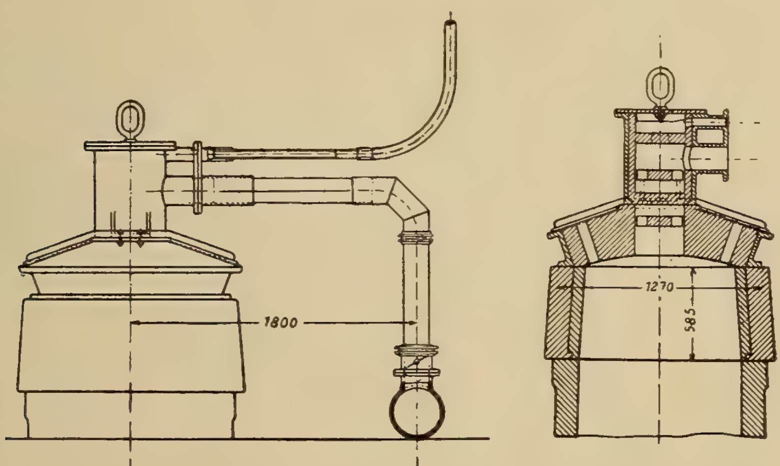


FIG. 18.—SECTIONS OF INGOTS, SHOWING THE EFFECT OF RETARDING THE COOLING OF THE TOP BY MEANS OF PLUMBAGO

FIG. 19.—SECTION OF INGOT CAST IN A MOULD WITH A SAND LINING AROUND THE TOP, AND USING PLUMBAGO

will be noticed that the degree of taper varied greatly in the different experiments. Likewise the character of the material was quite diverse. But in all cases, without exception, this method of compelling the solidification of the axial portion to proceed from below upwards resulted in very considerable correction of the tendency to piping. There seems to be a commercial objection to casting rail ingots with the big end up on account of the possible complexities which would thus be brought about in the methods of handling the ingots and moulds. But this would not seem to present any insuperable difficulties, especially when we remember that the preservation of a large part of an ingot from the scrap pile is to be put upon the credit side of any system. In fact, Prof. Howe has suggested the essentials of a method of procedure in his elaborate investigation of "Piping and Segregation in Steel Ingots."* This might need modification or even entire replacement. It would hardly seem possible, however, that a mechanical detail of this description should be permitted to interfere with tests to a finish of the big-end-up method with Bessemer and open-hearth steel ingots of rail size.

Still another method which has been found to give good results relates to the arrangement of a sinking head. That is to say, the upper portion of the mould is prolonged. This prolongation may be made of fire-brick or other suitable material. It is then heated to a high temperature before proceeding with the teeming. In this way a reservoir of melted metal and a hot top may be maintained until solidification of the body of the ingot. In Fig. 17 is shown an ingot cast in accordance with this method.† The prolonged portion was made of smaller cross-section, as may be seen from the illustration. Mr. A. A. Stevenson reports successful results from the use of plumbago. Thus, Fig. 18 discloses sections of the tops of two ingots during the casting of which this material was employed. It was placed on the top when the molten metal had nearly reached the upper limit of the mould. In Fig. 19 is shown the top of another ingot, similarly cast. Mr. Stevenson states that



FIGS. 20 AND 21.—GAS FURNACE DEVISED BY J. RIEMER FOR INGOTS FROM 5 TO 20 TONS

*Trans. Am. Institute Mining Engineers, Vol. XXXVIII., 1907.

†Reported by Prof. Howe from a private letter from Mr. Trotz.

plumbago was used in connection with a sand lining at the top of the mould.

The idea of the maintenance of the head of the ingot in a molten condition during the solidification of the main portion has been carried out in a very thorough manner by Herr Julius Riemer. His process has been thoroughly tried out by the firm of Haniel & Lueg, Düsseldorf-Grafenberg, Germany. At the beginning of 1906 this firm had shipped to England, and there had been accepted through the Board of Trade, upwards of 4,000 shafts, in the production of which by the Riemer process it had kept its discard of 10 per cent. or less. These facts give point to a consideration of this method of procedure.

Riemer cites attempts at the problem through heating the top of the ingot, showing that this fundamental idea had dawned forty or more years ago. Krupp years ago poured upon the head of the newly formed ingot a mass of molten slag. It is not impossible that this method is still in use at the Krupp Works. But aside from the great ironmaster of Essen, Riemer finds that these early investigators did not make any permanent impression upon the practice of ingot-casting. They had, he thinks, the true fundamental idea. Apparently, they failed in its application for two reasons, (1) because they did not bring to bear a sufficient amount of heat, or (2) because they did not apply the heat with sufficient quickness. Riemer found, upon experiment, that a temperature must be at hand which is considerably higher than the melting point of the steel, and that the application must take place within a few seconds of the completion of teeming.

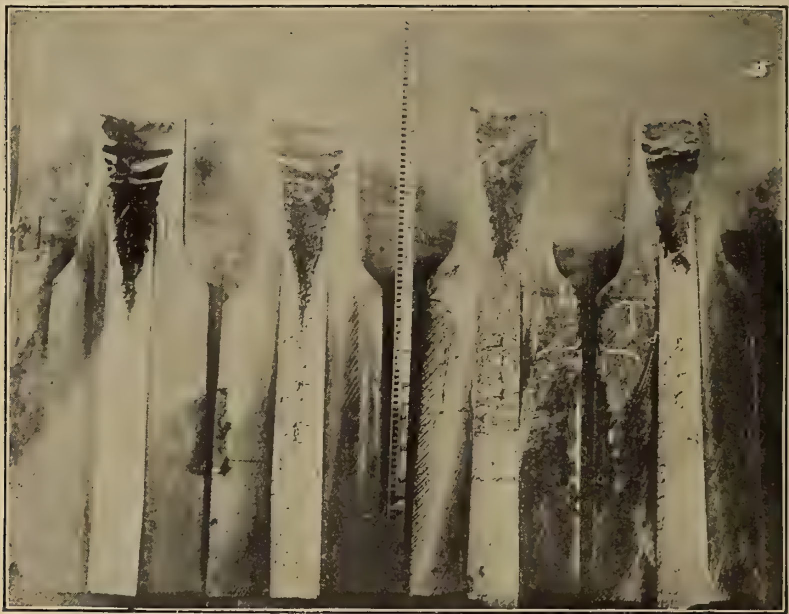


FIG. 22.—THE GOLDSCHMIDT THERMIT PROCESS. LEFT-HAND INGOT CAST IN THE ORDINARY WAY. RIGHT-HAND INGOT CAST BY THERMIT PROCESS. FEEDING HEAD USED IN BOTH CASES

A view of the Riemer appliance suited to ingots of 5 to 20 tons may be seen in Fig. 20. This apparatus is essentially a gas furnace supplied with atmospheric air under pressure and with some suitable fuel gas. The

piping to supply the air and gas may be seen to one side. Above is the eye, by means of which the apparatus may be placed in position upon the head of the newly cast ingot. In accordance with this system, not only is the heat applied at once, but an intense temperature is reached practically without any delay. In order to obtain a sufficiently high temperature of the flame, both gas and air are strongly preheated by a suitable device. Riemer obtains a very intense heat applicable to the head of the ingot, and thus prevents the formation of a crust at the top. Consequently, at no time is the escape of gas bubbles prevented. Compression from above—as in the Whitworth system—is objectionable for the very reason that it is difficult, if not impossible, to permit the gas bubbles to find an exit. Further, if a crust is not allowed to form at all, its remelting will, of course, not be required. Riemer thinks that the remelting might have bad results from the dropping down of softened, but not completely melted, pieces. Fig. 21 gives a sectional view of this furnace.

That this system of Riemer is competent to produce not only an ingot having a short pipe, but one of a high degree of chemical homogeneity, may be learned from certain analyses which have been made of different portions of the two 1½-ton ingots cast in accordance with his method. It is not necessary, perhaps, to give these in full. Suffice it to say that, in both cases, eight samples were taken along the longitudinal axis and four from near the lateral surface, while in the one case five additional samples were taken from intermediate positions. In this latter ingot, if we omit the

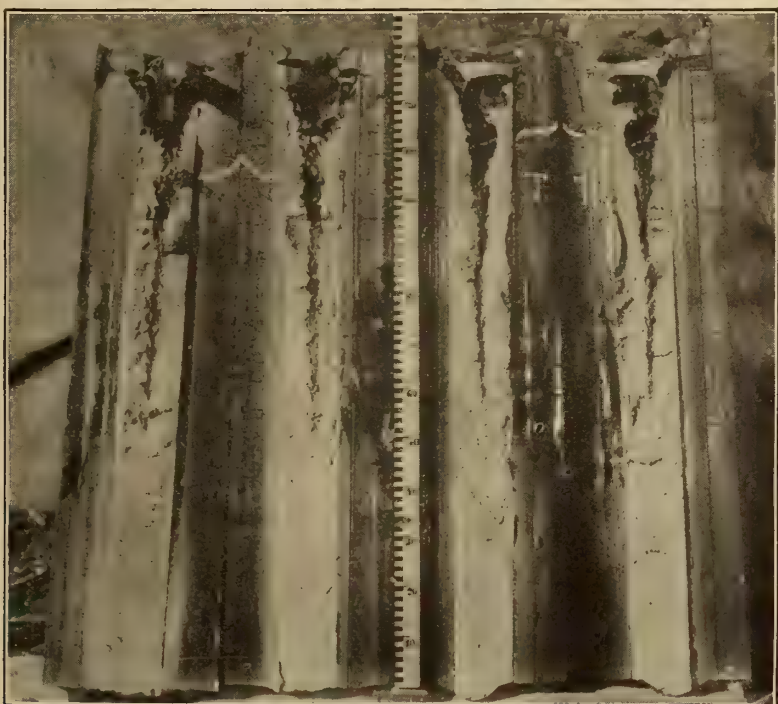


FIG. 23.—SAME METHODS USED AS PER FIG. 22, ONLY NO SINKING HEADS WERE EMPLOYED

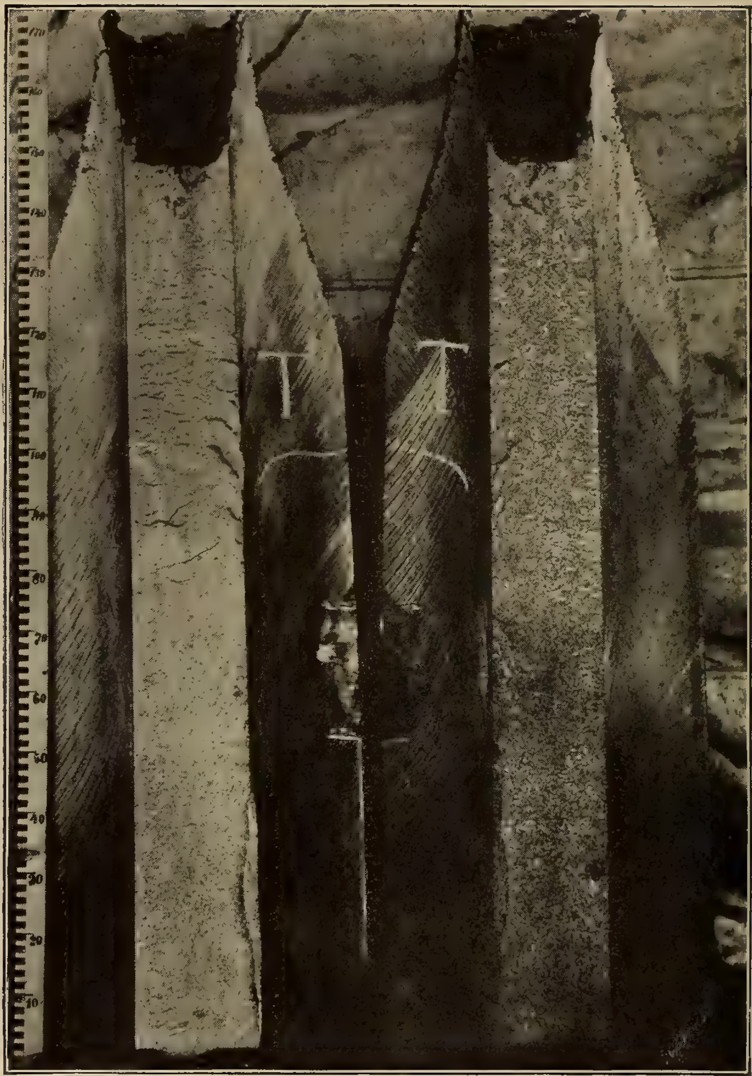


FIG. 24.—INGOT CAST BY USING THE THERMIT PROCESS COMBINED WITH A HOT TOP

position immediately below the bottom of the trifling pipe, the carbon percentage had a short range from .22 per cent. to .25 per cent.; the sulphur varied from .028 per cent. to .044 per cent.; the phosphorus showed a variation from .032 per cent. to 0.49 per cent. The sample from the position in the axis immediately below the pipe yielded the following percentages: carbon .41 per cent., sulphur .160 per cent., phosphorus .150 per cent. In the other ingot, omitting the first two positions below the bottom of the pipe, the carbon ranged from .33 per cent. to .39 per cent; the sulphur from .024 per cent. to .033 per cent.; the phosphorus from .022 per cent. to .035 per cent. The two positions omitted disclosed the following results: Immediately below the pipe, carbon .73 per cent, sulphur .130 per cent., phosphorus .117 per cent.; next position below,

carbon .50 per cent., sulphur .057 per cent., phosphorus .66 per cent. This last position was apparently about 12½ per cent. of the total length below the extreme top of the ingot. It will now be seen from these two cases that a moderate discard would eliminate not only the pipe, but the segregation as well.

Still another method of procedure is that which effects its results by the use of the Goldschmidt anti-piping thermit. This substance is composed of aluminum and iron-oxide. Upon the application of sufficient heat, a chemical reaction takes place in which the oxygen is transferred to the aluminum, forming an oxide and setting free the iron. There results a kind of iron or steel. Now when a steel ingot has been cast and the pipe has been allowed to form—that is to say, after the lapse of 15 or 20 minutes subsequent to completion of the teeming—a box containing the thermit is introduced from above, by means of an iron rod, into the body of the casting. Immediately a violent reaction takes place, resulting in the release of an enormous amount of heat and the rise of slag to the surface. This slag is removed and some fresh molten steel introduced. Experiments are now being conducted at one of the largest American steel works. In Hungary the government steel works, located at Diosgyör, have been using this method, and report satisfaction.

In Figs. 22, 23 and 24 are shown examples of the use of this preparation. In the first of these figures, however, the left-hand ingot (two halves) was cast without the use of the thermit, while the right-hand ingot discloses the result of its application. In both cases a feeding-head was used. This was formed of refractory brick and heated. It will be noticed that the cross-section of the head is much reduced from that of the body of the ingot. That this reduction of diameter and provision of a heated casing is, even when used alone, a pretty effective means of pipe reduction, may be seen from the former of these ingots. The length of pipe reaching down into the ingot-body is not great, while the weight of metal discard belonging to the head itself is small. However, the treatment by thermit practically eliminated all pipe from the main portion and confined it to the sinking-head. The precise reduction of the pipe is from 1,070 mm. without thermit to 1,005 mm. with it—that is, 65 mm. (= 2½ inches). See Fig. 22. In casting ingots without sinking-heads—one with thermit, one without—a reduction was made from 842 mm. to 780 mm. See Fig. 23. This would seem to show that thermit exerts some influence, though not of a striking character. As to cost, this would be about $1 per ton of metal treated.

In Fig. 24 we have an example of a large ingot, which was also cast by the thermit process. The combined effectiveness of thermit and a hot top may be seen at a glance. The actual weight of discard is quite negligible.

CRANK SHAFTS FOR GAS ENGINES

By Horace Allen

OWING to the high initial pressure developed in the cylinders of internal combustion engines on the ignition of the charge, the proportions of the crankshaft cannot be arrived at by the application of the formula usually adopted for steam engines; at least, gas-engine builders do not adopt these formulæ, nor do they agree in the substitution of any formulæ which they might consider as giving the most suitable proportions for such crankshafts, as is shown by the divergencies from any fixed rule in modern gas engines.

To obtain a high degree of thermal efficiency, it is necessary that the compression shall be carried as high as the quality of the gaseous fuel will permit without premature ignition, and increase in compression is accompanied by increased initial explosive pressure. In modern gas engines the maximum explosive pressure ranges from 300 to 600 pounds, while in the case of steam engines it is seldom higher than 150 to 250 pounds per square inch.

The thermal efficiency of an internal combustion engine is highest when the maximum of heat development occurs at constant volume, so that the maximum initial pressure is usually exerted when the crank is on the dead centre.

To illustrate these conditions diagram Fig. 1 has been prepared to show the manner in which the pressure in the cylinder is transmitted to the crankshaft by a connecting rod of a length equal to five times the crank.

The dotted line *A B* shows the pressure line as obtained from an indicator diagram, while the full line *C D* shows how the pressure exerted on the crank is modified by the inertia of the reciprocating parts (60 pounds per square inch being taken in this example); a maximum initial pressure of 350 pounds developed in the cylinder becoming an effective pressure of 300 pounds per square inch on the piston.

As the crank is on the dead centre, there is no turning effort; but the whole of the pressure becomes a thrust on the crank-pin.

The dotted curve *N O* shows (on the same scale as the vertical line on the left of the diagram) this thrust throughout the power stroke of a single Otto cycle cylinder. The full-line curve *M* also shows the turning pressure developed as the crank advances.

For crankshafts as usually constructed, the proportions are first worked out by calculating the combined stresses due to twisting and bending.

To take, for example, a worked-out case:*

Bending moment, 7.1 foot-tons.
Twisting moment, 19.0 foot-tons.
Combined moment, 27.37 foot-tons.

However, it is seldom that the proportions of crankshafts given by calculation are adopted in practice, and the advice given to the writer by an experienced mechanical engineer—to carefully ascertain the proportions required, by calculation, and then put a lump on—is the rule rather than the exception.

As the physical properties of ma-

* "Practical Treatise on the Otto Cycle Gas Engine," by W. Norris.

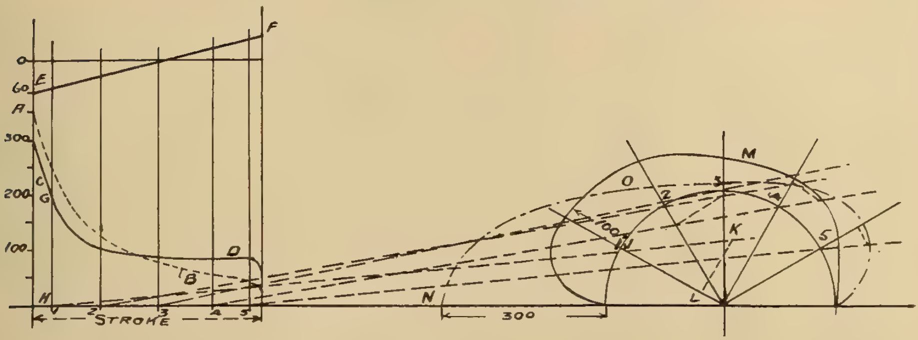


FIG. 1.—DIAGRAM SHOWING THE BENDING AND TWISTING STRESSES ON A GAS ENGINE CRANKSHAFT

Bending: 300 pounds × area of piston in square inches.
Twisting: 100 pounds × area of piston in square inches × length of crank in inches.

Taking the cylinder diameter at 27 inches and the crank 15 inches:
Bending stress, 171,767 pounds.
Twisting stress, 858,825 pounds.

terials are usually determined from tests made on specimens which cannot be considered as representative of the same material as practically applied, the results obtained have to be subjected to a system of guessing, or rather judgment. No practical man would consider that a test result from a bar 1 inch in diameter, breaking with 1,400 pounds at the end of a lever 1 foot long, would apply to a crankshaft of, say, 12 inches diameter, so he has to make what he considers a safe allowance. Also, the larger the bulk of the steel forging, the less the reliance that can be placed upon the adoption of results obtained from small specimens, as the physical treatment of such forging cannot completely solidify the steel and eradicate blowholes and other defects.

As the proportions of the crankshaft increase over that of the test specimen, the designer has to use his judgment in reducing the safe stress to which it may be subjected, and for this reason every increase of bulk in a shaft forging means an increase in the factor of safety to be allowed.

Therefore, the less the diameter of the shaft, and bulk of forging, the nearer will the safe-working stress approach the results obtained by test, as is frequently confirmed by the failure of large crankshafts.

If, now, it was possible to eliminate the bending moment from consideration, there would only be the twisting moment to deal with, and the figures given indicate that this may be about one-fifth of the total stress when taken as combined bending and twisting. While it is not within the power of the designer to totally eliminate the stresses due to bending, it is possible to reduce this to a minimum. To illustrate this, Fig. 2 is a diagrammatic sketch of a crankshaft as usually designed.

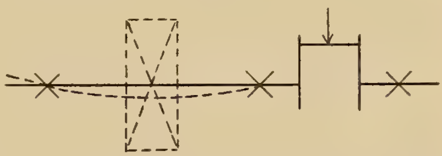


FIG. 2.—BENDING OF A CRANKSHAFT AS USUALLY DESIGNED

Under a bending stress, due to the maximum initial explosive pressure, this shaft would be strained, as shown by the exaggerated sketch, Fig. 3.

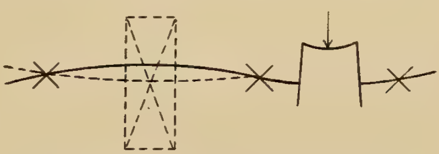


FIG. 3.—BENDING OF A CRANKSHAFT DUE TO EXPLOSIVE PRESSURE

The addition of a heavy fly-wheel would further complicate the matter, as shown by the dotted lines.

At this stage it will be obvious that there are not only bending strains set up, but that the revolving of the shaft would result in these strains being reversed in proportion to the speed of revolution. In his annual report on "Engine Break-downs,"* Mr. Longridge refers to three cases of crankshaft failures, but not before they had made 293, 198 and 227 million revolutions, respectively; the diameters being 8⅞ inches in the first case and 11½ inches in the third.

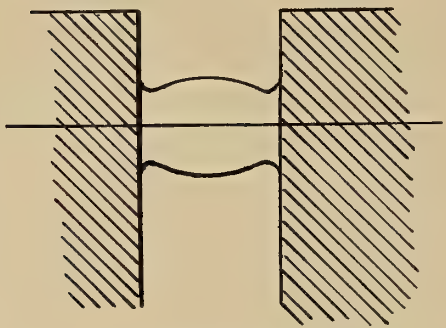


FIG. 4.—CONSTRUCTION OF CRANK-PIN SUGGESTED TO PREVENT BENDING

Bending strains are not only set up by the pressure on the crank-pin, but also by the weight of the fly-wheel, while a third strain may be due to the manner in which the power is transmitted to machinery.

Referring to the sketches, the points of fracture due to bending strains would either be in the crank-pin or the main bearing between the crank and fly-wheel; while the points of support have been shown at considerable distance apart. To minimize the bending strains, the writer suggests that a crankshaft might be designed on the following lines:

To prevent bending of the crank-pin, it might be made of increased diameter in the middle, as in Fig. 4, and to reduce the distance between the main bearings, the disc type of crank (Fig. 5) could be adopted, and the periphery made the main bearing.

The closing in of the main bearings would allow of a construction of fly-wheel somewhat as sketched, where the weight would be carried quite close to the points of support and the tendency to bending almost removed.

The chief difficulty in this construction is the peripheral speed of the crank discs, which would be in the neighborhood of 2,500 feet per minute; but this might be met by the adoption of roller bearings or anti-friction wheels in the positions indicated by the dotted circles in Fig. 6.

Mr. Michael Longridge further gives the following formulæ for the best modern practice in designing crankshafts for gas engines:

Gas engines with cylinders up to 12 inches diameter:

$$C^2 \ (l + d) \div D^3 = 10 \text{ to } 11$$

Cylinders with 20-inch diameter cylinders:

$$C^2 \ (l + d) \div D^3 = 15$$

Small gas engines:

$$C^2 \ r \div d^3 = 10 \text{ to } 11$$

Large gas engines:

$$C^2 \ r \div d^3 = 13$$

Where C = cylinder diameter,
D = diameter of crank-pin,
d = diameter of journal,
l = distance between the inner ends of the bearings on each side of the crank,
r = length of the crank arm.

All dimensions being in inches.

From a consideration of the breakdown of a number of crankshafts, Mr. Longridge found that in one case, neglecting the inertia of the reciprocating parts, etc., the maximum bending moment must have been 5,400 pounds per square inch, and the combined bending and twisting moments 6,450 pounds per square

* "Engineer," Oct. 11, 1907.

inch; so that if a shaft could be designed with a minimum bending stress, there would be a margin of 16 per cent. to the advantage of the new design. Mr. Longridge comes to the general conclusion, in the case of some of the steam-engine shaft breakdowns, that as long as the stress does not exceed 7,000 pounds per square inch, it matters little whether there are, or are not, sudden changes in section.

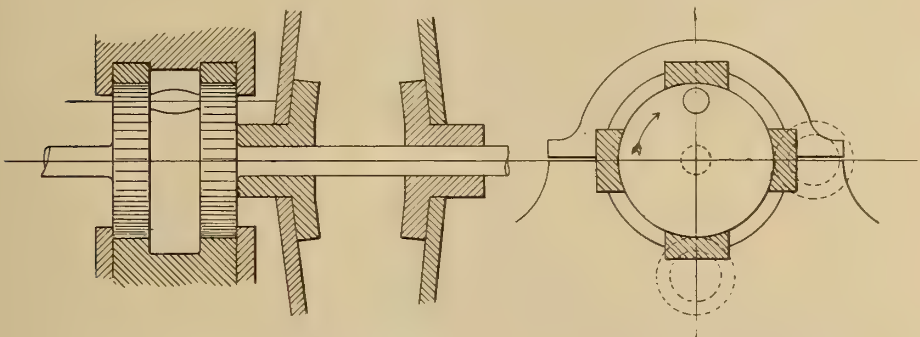
with $u = \dfrac{cK}{y}\,\dfrac{v^n}{p}$ and

$n = \frac{1}{2}$ at 100-foot speed,
$\quad\;\; 0$ at 3,600-foot speed,

the reduction in friction and the heating effect on the bearings can be approximately arrived at:

$$\text{Thermal units per minute} = \frac{P\,u\,S}{772}$$

The dimensions of the crank-pin,



FIGS. 5 AND 6.—SUGGESTION FOR IMPROVED DESIGN FOR CRANKSHAFTS AND FLYWHEEL

In regard to the increase in diameter of the main bearings to that of a disc, including the crank-pin, and the resulting increase in rubbing surface speed: according to Dr. J. I. Nicholson,* the frictional loss would be reduced owing to the fact that the higher surface speed would cause the temperature of the lubricant to be higher in proportion to the temperature of the bearing than in the present type of bearing, and thus the coefficient of friction would be less.

If the foot-pounds of work done per minute varies as $P\ u\ S$

Where P = total pressure on bearings, pounds,
u = coefficient of friction,
S = peripheral speed in feet per minute,

taking the length multiplied by the diameter, should be proportioned to a total pressure of between 400 and 500 pounds per square inch; but the part of the shaft which has only to transmit the twisting stress can be kept down much less in diameter in the new design proposed.

To take, for example, a single-cylinder Otto cycle gas engine, in which the maximum initial pressure is 300 pounds per square inch, and cylinder diameter 27 inches and crank 15 inches, the diameter of the shaft, when only twisting stress is provided for, as in the formula:

$$D = \sqrt[3]{\frac{T}{f}} \times 5.1 = 11.3 \text{ inches}$$

Where D = diameter of crankshaft,
T = twisting moment = area of piston × maximum pressure × length of crank in inches,
f = 9,000 for steel.

* "Friction and Lubrication." Paper read before the Manchester Association of Engineers, Nov. 23, 1907.

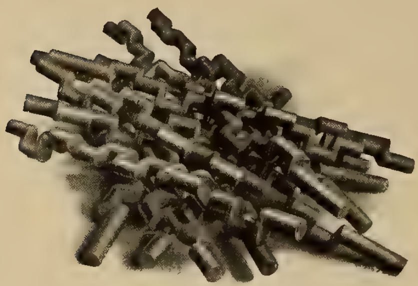
The crank-pin, of the direct thrust of the maximum pressure on the piston, is 300 pounds, on the dead centre, and allowing 450 pounds per square inch, diameter × length, should have an area of 382 inches, or, say, 19½ inches diameter × 19½ inches length.

If calculated upon

$$D = \sqrt[3]{\frac{l \times P \times d^2}{3 \times f}} \quad 11\tfrac{1}{2} \text{ inches}$$

Where l = length of crank in inches,
P = absolute pressure in pounds per square inch + 15 pounds,
d = diameter of piston,
f = constant 740,

and these results show that a shaft of 11½ inches diameter would be suitable to communicate the twisting stress of the cylinder without being liable to break down from the action of reversal of bending strains during an unlimited life, providing that the reversal of bending strains is reduced to a minimum as proposed in the new arrangement.



Current Topics

AS usual with the beginning of a new year, various reviews of the past twelve months appear, and the important elements in human progress are discussed and compared. It is not possible, at such close range, to select the events which are to have the most profound influence upon the development of mankind, and a study of the past will show that the really controlling features of any period were almost unappreciated at the time of their origin. At the same time, it must be admitted that the year just closed was remarkable for the demonstrations which it witnessed in the art of navigating the air. In both departments of effort—in ballooning and in mechanical flight—the public exhibitions have far exceeded anything which has heretofore occurred.

The great voyage of Count Zeppelin, covering more than 300 miles in the air, with a machine under full control, cannot be effaced by the misfortune with which it closed; while the achievements of the Wright brothers, both in the United States and in France, have shown the extent to which the aeroplane has been developed.

It must be remembered, however, that these displays are but the culminations of years of patient study, effort and hard work, following upon the partial failures or temporary successes of less fortunate predecessors.

The dirigible balloon, as it at present exists, is an improvement over *La France*, of the late Colonel Renard, only in the possibilities which the production of the high-powered, light-weight, internal-combustion motor have given it; and it is to the memorable trip of Renard and Krebs, in 1884, too little appreciated at the time, that the success of 1908 is due.

In like manner the successes of the Wrights have grown out of their own persevering efforts at gliding flight, following upon the work of their predecessor Lilienthal, and aided by the engineering skill and suggestions of Octave Chanute. The work of Langley in this field also must not be forgotten, and so we are again reminded that no effect is the result of a single cause, but is itself but one of the resultants of many causes, some of which can scarcely be traced, and many of which were almost wholly unappreciated when their influence was most powerful.

THE railroad situation in the United States is at present in a transition state—a state which is practically unique, and which, so far as the general public is concerned, is by no means fully appreciated. It is true that the history of American railroading has been one of continual development, both as regards the construction of new lines and the reconstruction of portions of the older systems; but the rapid development of the country during the past decade, with its accompanying increase in all that pertains to transportation facilities, has brought with it such demands for heavier equipment, speedier trains, easier grades and fewer curves that the whole problem has to be faced anew.

The rail question has been already discussed at length in these pages, both as to the demand for heavier rails to sustain the heavier wheel loads and for material of the highest quality to withstand the repeated stresses of more frequent service. The extent to which the use of heavier trains is causing the rebuilding of bridges, viaducts and trestles will be set forth in important papers now in course of preparation. The demand for more convenient terminal facilities in great cities is arousing discussion not only as to the best form, but also as to the urgent necessity for continually increasing expenditures in this direction. The public is demanding better and better service, and these demands involve the wise and judicious expenditure of vast sums of money.

That such expenditures are justifiable, in view of the great value which they represent, few will deny. In fact, it is just such expenditures, distributed necessarily among many important departments of engineering industry, which make for business activity of a kind which will react upon the prosperity of the railroads themselves, and hence act to stimulate the development of the country as a whole. Such expenditures, however, can be incurred only if corresponding increase in revenues can safely be assured. So far as the monetary value of improvements in railroad equipment is concerned, it is well understood that revenue cannot be expected from new works until after such works have been made effective. That is, the improved facilities must be supplied before they can earn income. This means that the money for their construction must be raised upon the prospective earnings which the improvements may be expected to produce: that the railroads, like other industrial enterprises, should be able to capitalize their future earning capacity. Such a capitalization is not difficult, all other things being equal. But all other things are not always equal; on the contrary, there exists such a disposition in some quarters to attack the railway interests and to impair their opportunities for raising funds that it seems opportune at the present time to call attention to the facts in the case.

No one, brought fairly face to face with the question, is disposed to minimize the tremendous possibilities in the development of the industries of the United States. No one who possesses any grasp of affairs can fail to realize the fact that the transportation facilities of such a country must share to an enormous extent in the development of the country as a whole. But in order that the transportation facilities may keep pace with this development, or, rather, in order that they may lead it, their true position should be appreciated. Instead of being selected as a target for attack from high places and from low, they should be recognized as enormous tools by means of which the work of developing the resources of the nation must be effected.

THE new magnetic-survey yacht now under construction for the Carnegie Institution is interesting in many ways, both by reason of the absence of iron, steel or other magnetic metals as far as possible, and also because of the gen-

eral completeness of the equipment with which it is to be provided.

An especial feature of interest, however, appears in the fact that the vessel is to be equipped with an auxiliary power plant, consisting of gas producer and gas engine. The *Carnegie,* as the yacht is to be called, is a wooden vessel of 568 tons displacement, intended to be navigated under sail, as a rule, but with a gas-power plant provided for purposes of manœuvring in port, and also for motive power when the wind is found insufficient.

The power plant includes a gas-producer, adapted for anthracite coal, and capable of gasifying 130 pounds per hour, which is sufficient for the 125 horse-power, six-cylinder engine, since a consumption of one pound per horse-power per hour is accepted as entirely practicable with the modern internal-combustion engine. This power is capable of propelling the vessel at a speed of six knots, so that the bunker capacity of only 25 tons of coal is sufficient to secure a power cruising-radius of more than 2,000 miles. In order to provide for the non-magnetic requirement of the equipment of the vessel the power machinery is composed of various bronze alloys, the only portions of the engine not conforming with this requirement being the thin cast-iron liners in the engine cylinders and the steel cams of the valve gear, these, however, being of insufficient magnitude to exert any appreciable influence upon the magnetic investigations in which the vessel is to be employed.

The fact that the internal-combustion engine has been accepted for a vessel of such importance as the *Carnegie* is sufficient indication of the assurance that such motive power is wholly reliable, and the moderate size of the boat is no bar to the obvious conclusion that such motive power may not soon come into service for much larger vessels. The real obstacle to be overcome in order that gas power may be more generally employed on shipboard seems rather to be in the question of devising a satisfactory producer for use with bituminous coal. The progress which has been made in this direction, however, leads us to believe that this difficulty will be wholly overcome, and that gas, free from objectionable tarry products, and suitable for use in the combustion engine, will soon be made from coals high in volatile matter. This being accomplished, there seems to be no reason why the internal-combustion engine, with all its advantages of high fuel economy, entire absence of smoke and freedom from all the difficulties attending the generation of steam at sea, will become an accepted type for marine power. The extent to which producers dispensing with the use of any vapour or water has been devised removes the objection as to the employment of salt water, so that the way appears to be opening for a most extensive development of an important department of gas power.

SAMUEL JAMES POPE THEARLE

A BIOGRAPHICAL SKETCH

THE fame of Lloyd's Register of Shipping has spread over the entire commercial world, since its rules and methods exercise a controlling influence upon both naval and merchant marine. For this reason the personality of the men by whom its work is conducted must be of interest, especially to the engineering profession in the important departments of shipbuilding and marine-engine design.

We have the privilege of presenting in this issue the portrait of Mr. S. J. P. Thearle, well known as an authority on shipbuilding, by whom the important article upon the "Design and Building of Cargo Steamers" in the Special Marine Number of CASSIER'S MAGAZINE for November, 1908, was written.

Mr. Thearle was born in Devonport, England, in 1846, and received his education both at that place and in the Royal School of Naval Architecture, South Kensington, of which institution he holds the diploma of Fellow. He was engaged in the construction department of the Admiralty and in the inspection of ships built by contract for the Royal Navy during the period from 1869 to 1876. In the latter year he joined Lloyd's Register of Shipping as surveyor, and, after being engaged in different parts of the country, he was appointed, in 1900, to the position of assistant to the Chief Ship Surveyor, at the head office in Fenchurch street, London.

Mr. Thearle is a member of the Institution of Naval Architects, and is a member of its Council; and he is also a member of the Institution of Engineers and Shipbuilders in Scotland, and of the Iron and Steel Institute. He is the author of a number of books relating to his profession, among which may be mentioned: "The Laying-off and Building of Wood, Iron and Composite Ships," "Treatise on Theoretical Naval Architecture," "The Modern Practice of Shipbuilding in Iron and Steel," together with various contributions to professional societies.

PHOTOGRAPH BY COLBY, MANCHESTER

CHIEF ENGINEER CHAS. H. MANNING, U. S. N., RETIRED

General Superintendent Amoskeag Manufacturing Company

See page 544.

CASSIER'S MAGAZINE

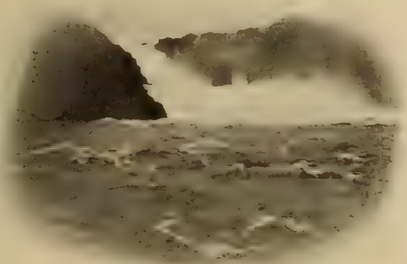
VOL. XXXV FEBRUARY, 1909 No. 4

THE WHITE COAL OF SWEDEN

A STUDY OF THE DEVELOPMENT OF THE HYDRAULIC POWER OF SCANDINAVIA

By John George Leigh

While many countries are at the present time taking an account of stock of their waning natural resources, with a view to thrifty conservation, there are still many parts of the world which are either undeveloped or are just beginning to enter upon a vigorous exploitation of their natural sources of wealth. The Scandinavian Peninsula is especially rich in water-power, for the most part undeveloped, and it is believed that the present article and its successors represent the first exhaustive view of its great wealth in this respect, a view obtained both by the personal investigations of the author and by the immediate co-operation of the Swedish Government, and hence authoritative and reliable.—THE EDITOR.



STORA SJÖFALLET, LULE RIVER, BETWEEN LAKES KARTJAJAUR AND LANGASJAUR

TO compensate the Swedes for a niggard store of fossil coal, Nature has endowed their land with many benefits denied to other countries. Prominent among these are abundant deposits of iron ores, world-famous for their excellent qualities; vast forests, which have placed Sweden in the forefront among producers of wrought and unwrought timber; and, last to be mentioned but not least in significance, water systems, impossible to over-value as actual and potential sources of national wealth.

In contributing to the past greatness of Sweden, her rivers and lakes played a considerable part, not only as convenient means of communication and transport but also as actual sources of energy. Water-driven sawmills were certainly known many centuries ago. So also was the use of water power in mining and metalworking, for pumps and hoisting machinery at the mines and hammers at the forges derived their energy from water-wheels. Even power transmission over considerable distances was employed, for that mechanical genius, Kristofer Polhem (1661-1751), the first of a long line of Swedish engineers to acquire European and American fame, constructed so-called "konstganger"—wooden beams hinged in a peculiar manner—by which power was transmitted by reciprocating motion over distances of several thousand feet. To-day, in some of the mining districts, one may still see applications of these "konstganger" in actual operation.

With the introduction of the steam engine came the promotion of the Swedish sawmill industry to the dignity of a manufacture. Before the second half of the nineteenth century the mills were usually located at

MAP OF COMPARATIVE ELEVATION OF SWEDEN

WATER SYSTEMS OF SWEDEN

I., Norrland; *II.*, East Central; *III.*, Lake Vettern and Motala River; *IV.*, Småland and Blekinge; *V.*, Halland; *VI.*, Lake Venern and Göta River; ● Principal State Waterfalls.

waterfalls near, but not actually on, the coast, with the result that the sawn timber had either to be floated to the seaport, and so deteriorated in appearance or quality, or carted or towed thither in barges. Great advantages necessarily attended the establishment of steam sawmills at the ports themselves, but coal in no way contributed to them. It has always remained too scarce and dear to warrant the supercession in its favour of wood blocks and chips.

To the same influence was due the inability of Sweden—for a long period the greatest producer of iron in Europe—to meet the revolution in the mining industry caused by the larger employment of coal in the manufacture of pig. It also explains the fact that the vast mineral wealth of Lapland can still only be regarded as contributing to a trade in the raw product, and not, as it properly should, to home mechanical industry.

Lack of coal notwithstanding, Sweden has made during the past twenty years a by no means inauspicious entry into modern industrialism. Innumerable new branches of manufacture have been established, others already existing have increased their output again and again, and technical and mechanical skill occupy positions second to none in the national estimation. What the future has in store for the country none of us, of course, can tell; but of this we may rest assured, that it will not be unworthy of past greatness, or fail to take into account that wealth of power for industrial enterprise with which the land is so abundantly blessed.

Owing to the hitherto unchallenged supremacy of the steam engine, statistics of the production and consumption of coal have been an excellent test of a nation's industrial development. Applied to Sweden, however, they can represent only partial truths, owing to the fact that, in that country (and especially has this been the case during recent years), other fuel and water power have been used to a much larger extent than elsewhere. Nevertheless, the following table, showing (1) the average annual production of coal, and (2) the average annual value of coal and coke imports during equal periods since 1870, is not without interest:

	1870–75	1876–80	1881–86	1886–90	1891–95	1896–00	1900–05
Metric tons.........	50,397	93,434	150,606	178,516	203,390	235,626	307,733
£.........	140,000	700,000	872,000	1,270,000	1,637,000	2,942,000	3,135,000

TABLE OF AVERAGE ANNUAL PRODUCTION OF COAL, AND AVERAGE ANNUAL VALUE OF COAL AND COKE IMPORTS SINCE 1870

Coal is found in Skane, the southernmost province, in three districts having an aggregate area of about 800 square miles. In mining it, to reach the more valuable beds it is necessary to sink the shafts, not only through the often thick superficial deposits but also through the greater part of the coal-bearing formation itself. The depths, consequently, at which such beds are found varies considerably. For example, the coal seams at Höganës lie about 330 feet below the present surface, those of Bjuf about 100 feet, and those of Skromberga and Bosarp yet higher up. Those worth working vary in thickness between 1 foot and 3 feet, and usually rest upon layers of fireclay or shales, which are picked and sorted in the mines with the coal and furnish material for the manufacture of fireproof bricks, sewer pipes, etc. The coal is unfit for coke-making, nor is it used in the iron industry.

The remarkably effective manner in which the configuration of Sweden has lent itself to the creation of

water systems unrivaled throughout the world as aids to industrial development will be readily appreciated after reference to the maps printed on pages 456 and 457. The determining factor, so far at least as upper Sweden is concerned, is, of course, the mountain range running down the peninsula usually in a direction from N. N. E. to S. S. W. Between this and the Gulf of Bothnia are three more or less clearly defined belts—first, mountains and a series of great lakes, in area from 20 to 275 square miles, and situated between 870 feet and 1,380 feet above the sea level; then a morainic and marshy district, and finally a region covered with marine deposits. Through these belts, running generally from northwest to southeast, are numerous river valleys, divided one from the other by mountainous and forest-clad territory. In their character, therefore, the rivers on the east side of the watershed differ very noticeably from those which flow through Norway. In the one case, a gradual descent to the sea is made through extensive depressions; in the other, the rivers carry their waters down to the Atlantic in steep, narrow, and relatively short gorges.

Not without interest, as supplementing the map printed above, is the following table, compiled by Mr. G. Appelberg, showing the approximate distribution of the area of the country generally according to height above sea level:

Between Latitudes.	Total Area Sq. Kilom.	Sq. Kilometers Above the Sea Level of: More than 400 m.	400–200 m.	200–100 m.	Under 100 m.	Percentage: More than 400 m.	400–200 m.	200–100 m.	Under 100 m.
69–68	13,800	8,690	5,110	......	......	63	37	....	....
68–67	34,040	18,500	12,900	2,640	......	54.3	37.9	7.8	....
67–66	41,880	17,330	10,660	7,800	6,090	41.4	25.5	18.6	14.5
66–65	41,160	14,460	17,070	3,130	6,500	35.1	41.5	7.6	15.8
65–64	39,540	6,050	25,790	4,570	3,130	15.3	65.2	11.6	7.9
64–63	33,720	9,400	11,780	6,850	5,690	27.9	34.9	20.3	16.9
63–62	32,960	11,510	13,170	3,940	4,340	34.9	40	11.9	13.2
62–61	28,800	9,810	10,790	4,210	3,990	34	37.5	14.6	13.9
61–60	34,350	3,000	11,240	10,120	9,990	8.7	32.7	29.5	29.1
60–59	44,340	......	800	10,480	33,060	....	1.8	23.6	74.6
59–58	38,160	......	540	5,280	32,340	....	1.4	13.9	84.7
58–57	34,930	......	6,760	15,050	13,120	......	19.4	43	37.6
57–56	24,320	......	580	11,070	12,670	....	2.4	45.5	52.1
56–55	5,860	......	......	400	5,460	....	....	6.8	93.2
	447,860	98,750	127,190	85,540	136,380	22	28.4	19.1	30.5

TABLE OF DISTRIBUTION OF AREA ACCORDING TO HEIGHT ABOVE SEA LEVEL

In addition to a large number of smaller streams, Sweden possesses 102 main river systems, each with an area of more than 78 square miles. All these rivers have their source in the country itself, except one, which crosses the Finnish border, and eleven which rise in Norway. For the purpose of the present discussion all these waters may be conveniently grouped in six large and well-defined systems:

I. Norrland. The forty-eight river systems in this division have an aggregate drainage area of 120,000 square miles, and include twelve streams of considerable magnitude, viz.:

River.	Length, Miles.	Fall, Ft.	Discharge per Second, Cubic Ft.
Torne........	234	1,135	16,245
Kalix.........	209	1,630	12,360
Lule........	194	1,410	11,475
Pite..........	193	1,775	7,415
Skellefte......	206	1,580	7,770
Ume.........	238	1,710	12,890
Angerman.....	243	1,910	15,185
Indal.........	198	1,375	12,360
Ljungan......	170	1,845	6,005
Ljusnan......	231	2,850	9,360
Dal..........	284	2,195	12,890
Klar........	230	2,055	7,065

With the exception of the rivers Dal and Klar, practically all the water power in this region is awaiting utilization in the form of electrical energy. Among the most prominent falls are Porjusfallen, 160 feet, estimated horse-power 30,000; Harspranget, 250 feet, 46,000 horse-power; Edeforsen, 70 feet, 24,000 horse-power; Krangede Rapids, 60,000 horse-power; and Elfkarleö, 50 feet, 41,000 horse-power.

II. Eastern water systems of Central Sweden. Of these the most important are Lakes Mälaren and Hjälmaren, the first having an area of 455 square miles, 1.5 feet above sea level, and the second 190 square miles, 67 feet above sea level. Into them flow several rivers, mostly from the north and west, already harnessed to a large extent. The aggregate drainage area of this division is 12,000 square miles.

III. Lake Vettern and Motala River. This group includes Lake Vettern, the Motala and three smaller river systems, and has a drainage area of 6,600 square miles. The lake, which is the second largest in Sweden, 740 square miles in area, 290 feet above sea level, has its outflow through the Motala, which forms several important waterfalls, many of which are already provided with power stations. It is believed that, by slightly raising the level of the lake and regulating its discharge, the power now available might readily be doubled.

IV. Smaland and Blekinge. Included in this division, the drainage area of which is 8,600 square miles, are eighteen river systems and many falls, several already furnishing electrical energy.

TOURIST HUT AT HARSPRANGET FALLS, LULE RIVER. THE WATERS OF THE RIVER FALL 245 FEET IN A DISTANCE OF 1.2 MILES THROUGH NARROW, ROCKY CHANNELS. EFFECTIVE HORSE-POWER, LOW WATER, 22,348; MEAN INDUSTRIAL, 46,176

V. The Halland River systems are sixteen in number and embrace a drainage area of 8,200 square miles. The power of the four more important rivers—the Lagan, Nissan, Atran and Viskan—is largely developed.

VI. Lake Venern-Göta elf water system. This has a drainage area of

20,000 square miles, and may be described as the largest single river system in the Scandinavian peninsula. Venern—2,200 square miles 145 feet above sea level—is the most extensive fresh-water lake in Sweden, and, after the Russian lakes Ladoga and Onega, in Europe. Not far from its outlet, in the Göta River, are the Trollhätte Falls, with a head of 105 feet, the most important and valuable in the country. They belong to the State, and are now being equipped with extensive plant, which will be described in a later article. In the same water system also is the Gullspang fall, 65 feet, the power of which has, within the past few months, been converted into electrical energy.

STORA FÄLLFORSEN, PITE RIVER. HEIGHT, 19.5 FEET; EFFECTIVE HORSE-POWER, LOW WATER, 1,723; MEAN INDUSTRIAL, 2,767

Perhaps the most remarkable circumstance associated with the subject of this paper is the dearth of easily available and definite information. With the exception of a report on State waterfalls and certain legislative enactments, to which reference will be made in later pages, no official data accessible to the public can be said to exist, and of general literature on the subject there is an absolute dearth. The present, indeed, appears to be the first attempt ever made, even in Sweden, to approach the question from other than purely governmental or technical standpoints. The difficulties which had to be faced were, consequently, very considerable, and might, as a matter of fact, have proved destructive of the project but for the invaluable assistance extended to the author by the government itself. It is, therefore, with no ordinary feelings that I take this early opportunity of acknowledging my indebtedness to the latter, and, pre-eminently, to those officials of the Board of Trade to whom were committed the duty of compiling the desired information.

Notwithstanding the obvious and

generally recognized importance of such an inquiry, no official investigation has yet been made into the character and aggregate amount of water power available for hydro-electric enterprises. Significant advances in this direction have, however, to be noted, first, in connection with the waterfalls belonging to the State, and, secondly, by the creation last year of a Government Hydrographic Bureau. To this office—which, I learn, has already made considerable progress with the investigation of three leading water systems—has been entrusted the duties of studying, from a practical as well as scientific point of view, the entire water resources of the country, and of publishing the results in annual reports.

For the moment it may be stated—and this appears a conservative estimate—that the amount of water power which might be economically utilized as electrical energy within a reasonable time, and subject to some regulation of the lakes, is not less than 4,000,000 horse-power at the turbine shaft. Of this aggregate, 86 per cent. may be allotted to the Norrland group of river systems; 1.2 per cent. to Group No. II.; 1.4 to No. III.; 1.8 to No. IV.; 2.6 to No. V.; and 7 per cent. to the Venern-Göta group. As will be seen from the typical photographs included in the present article, the Swedish waterfalls are usually of limited height, heads of between 15 to 100 feet being the most common. Of falls of 1,000 feet or more, such as are found in Norway and Alpine countries, there are but few examples. In some of the projects, however, which now occupy public attention, it is proposed to utilize heads up to 650 feet.

THE KVARN FALLS, RAGUNDA, ON THE INDAL RIVER. HEIGHT, 52 FEET; EFFECTIVE HORSE-POWER, LOW WATER, 12,324; MEAN INDUSTRIAL, 28,914

Connected with most of the rivers are lakes, serviceable as storage reservoirs, from which the discharge may be evenly distributed over the year, or regulated according to temporary requirements. The amounts of rain and snow vary, of course, in different parts of the country; but the average yearly precipitation may be estimated at 23 inches and the

NORTH RISTA FALLS, ON THE AVE RIVER, A TRIBUTARY OF THE INDAL; HEIGHT, 122 FEET; EFFECTIVE POWER, LOW WATER, 2,617; MEAN INDUSTRIAL, 4,187

available normal flow at low water at about 20 per cent. of this amount, or, say, 0.36 cubic feet per second and square mile. In the unregulated rivers the discharge is subject to noteworthy periodical variations. For example, measurements of the Angerman vary from 5,600 to 75,000 cubic feet per second; of the Indal, from 2,700 to 70,000; and of the Göta, from 6,700 to 33,000. Speaking generally, there is little doubt that the

hydraulic installations necessary for the utilization of the energy at the falls can be put down without special difficulty or expense, and that the geological formations readily admit of reliable structures.

The State itself is the largest individual owner of waterfalls, possessing from 12 to 13 per cent. of the total number. During the years 1899-1903 a special committee undertook a very complete survey of this national property with a view to its eventual development. The committee's report, published in two volumes, deals seriatim with 271 more important and 105 smaller falls, and arrives at the conclusion that from the first-mentioned there may be obtained at low-water flow, *i. e.,* at all times, 400,000 horse-power at the turbines. A special estimate was also made of the mean industrial power obtainable during nine months of the year, and this was calculated at 775,000 horse-power, 535,000 horse-power being allotted to the northern and 240,000 horse-power to the southern parts of the country. All these figures, it should be noted, estimate the horse-power at the turbines at 75 per cent. of the natural energy, and are arrived at without consideration of possible lake regulation. Of the potential value of such regulation, a fall in Lapland, now nearing completion as a power station, affords excellent proof. The State Waterfalls Committee has estimated its low water and mean industrial energy at respectively 1,560 and 2,327 horse-power; but it has been found, by regulating and slightly raising the level of an adjacent lake, that 8,800 horse-power can be easily obtained.

TÄNNFORSEN FALLS, JEMTLAND, SITUATED MIDWAY BETWEEN LAKE STORSJÖN AND THE NORWEGIAN FRONTIER

During the past few years the government has bought up several waterfalls, to which, of course, no reference is made in the report of 1903. Among these are two in the Göta River, by the possession of which the State has secured complete control of the outflow from Lake Venern and a consequent increase from 80,000 to 190,-

000 horse-power of disposable energy. For the projected electrification of government railways the State has also purchased water power, well situated for the purpose, to the extent of about 30,000 horse-power.

To carry into effect a resolution, adopted some years ago, that the State should harness some of its falls and itself act as a distributor of electrical energy to the public, the Riksdag last year created as a government department a Waterfalls Board, consisting of a director and four other members. In this body are vested extensive powers, heretofore divided between different authorities. Under its control the great power station at Trollhätte is rapidly nearing completion, and other projects of like character are assuming a definite form. To the same board has also been entrusted the duty of preparing plans for the extension and development of the canal system of the country.

To Sweden belongs the credit of a very early recognition of the value of electric lighting; indeed, the first town in Europe to light its streets with the new illuminant was Hernösand in 1885. During the next few years many other towns, among them Orebro, Falun, Söderhamm, Gefle and Umea, were lighted by power directly derived from waterfalls, while others enlarged and supplemented in the same way their old steam centrals. It was not, however, until the great development of electric power transmission in the early '90's that extensive and systematic use was made of the abundant natural sources of energy so generously distributed throughout the country.

ÄLFKARLEBY FALLS, NEAR THE MOUTH OF THE DAL RIVER. HEIGHT, 49 FEET; EFFECTIVE HORSE-POWER, LOW WATER, 15,450 TO 15,750; MEAN INDUSTRIAL, 41,250

The first significant transmission of electric power was that of 1891-3 from Avesta, on the Dal River, to the Norberg mining field, a distance of 14¼ miles; and this was followed, in quick succession, by numerous enterprises of like character, very helpful to the then rapidly developing mining, iron and steel, electro-chemical, paper-making and pulp-mill industries. At first a considerable propor-

THE TOPPÖ FALLS TROLLHÄTTAN

tion of the machinery and appliances required for hydro-electric plants was of foreign origin, but for many years past such imports have been restricted to a few comparatively unimportant specialties. The home industry, as a matter of fact, so rapidly developed that it has been able not only to satisfy Swedish requirements, but also to meet successfully foreign competitors abroad—as witness the electrical rolling-mill of 850

horse-power and the two alternating-current machines aggregating 900 horse-power—delivered by the General Electric Manufacturing Company of Sweden to, respectively, the Hamilton Steel & Iron Works, of Canada, and the Marconi Wireless Telegraph Company, of London.

The Swedish company just mentioned, known at home as the Allmänna Svenska Elektriska Aktiebolaget, has its headquarters at Vesteräs, and is the largest of its kind in Northern Europe. Based originally upon the invention of Jonas Venström, famous, among other achievements, in connection with the three-phase system, this company last year celebrated its twenty-fifth anniversary. Other very prominent Swedish manufacturers of electro-mechanical plant are Luth & Rósens Electrical Company and the Amalgamated Electric Company, the latter a union, since January, 1907, of the Magnet and Holmia Companies, each of which played an energetic part in the early history of the industry. Well-known manufacturers of water-turbines, to mention but a few from a large number, are Nydquist & Holm, of Trollhättan, the Fynshyttan Company, and the Arboga & Kristinehamm Mechanical Works. Glass insulators, it may be noted, are not used in Sweden, most of the transmission plants being equipped with insulators manufactured at the porcelain factories at Rörstrand and Gustafsberg.

Reverting to the earliest applications of hydro-electric power to industrial undertakings, it may be pointed out that the Scandinavian mines were among the first to realize the advantages derivable from the use of electrical energy distributed from a common centre to their various machines, especially winding hoists and pumps. Following closely upon the Avesta-Norberg enterprise came the first three-phase transmission of note in Northern Europe, namely, from Hellsjön to the well-known Grängesberg mines, a distance of about 8½ miles. Originally, only about 300 horse-power were installed; now raised, however, to 2,500 horse-power, generated at three large separate stations, equipped by the General Electric Manufacturing Company, which has also supplied seventy motors for use in the mines themselves.

The results obtained from the first installation proved so encouraging that, within a very brief period, practically every large mining company in Central Sweden having suitable water power in its neighborhood applied for similar equipment. Among the more noteworthy installations may be mentioned the power station of 1,600 horse-power capacity of the Guldsmedhytte, Stripa & Strassa Company, with complete equipments for mining operations and magnetic ore-separation and briquetting on the Gröndel system; the Stribergs mines power station, of similar capacity; and the equipment of the zinc mines of the Belgian company, "La vieille Montagne," at the northern end of Lake Vettern.

The last-mentioned mines derive their power from a station at Näs belonging to the Motala River Power Supply Company, which has a capacity of 1,800 horse-power, and delivers current at a pressure of 20,000 volts to the towns of Motala, Vadstena and Askersund, the mines of Ammeberg, and the single-phase railway from Borensberg to Klockrike, to which fuller reference must be made in a later article.

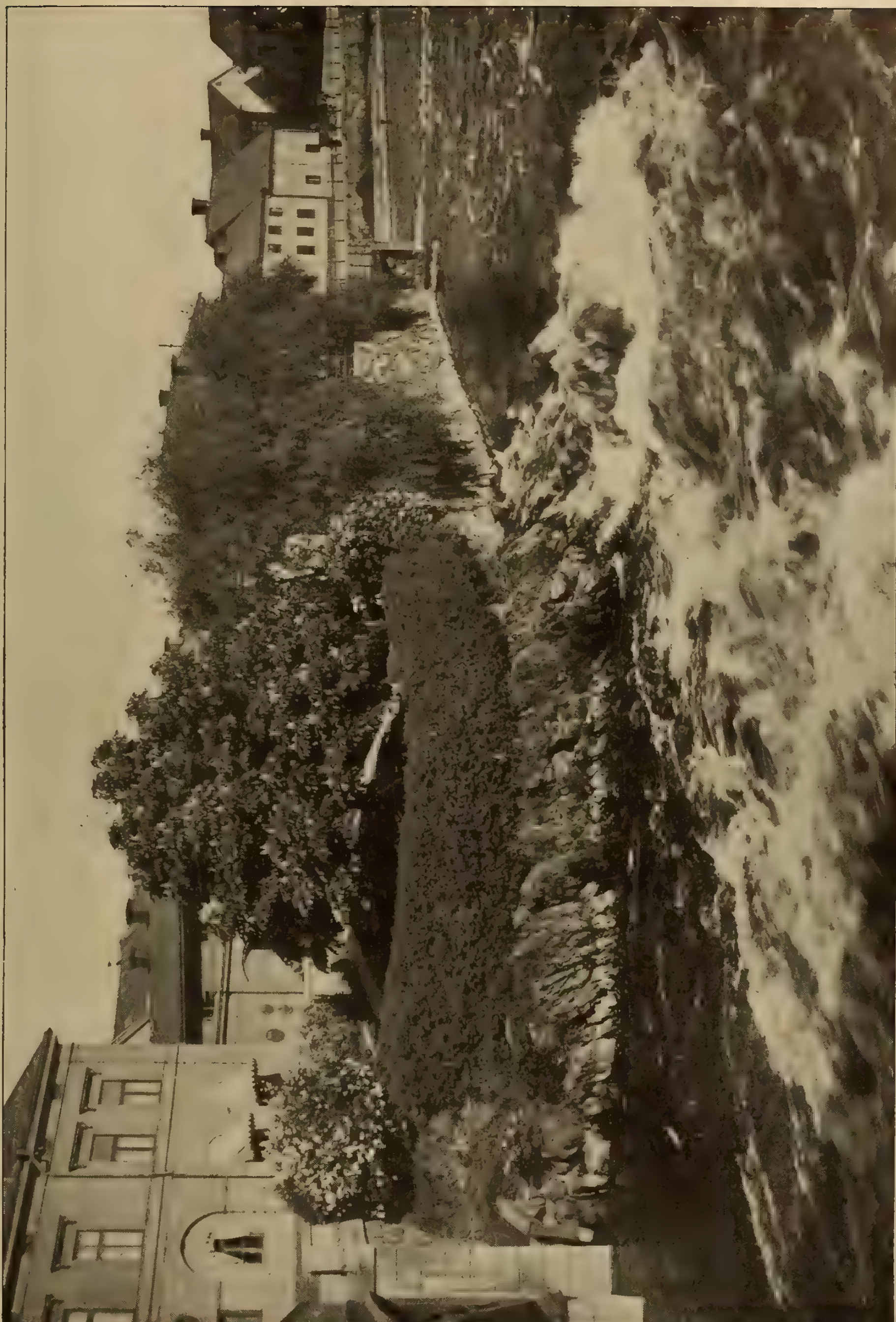
The first electrical rolling-mill, certainly in Scandinavia, and probably in the world, was equipped in the early '90's by the G. E. M. Company of Sweden for the Boxholms Ironworks Company. This was very rapidly followed by the installation of hydro-electric machinery at Hofors, Domnarfvet, Surshammar, Fagersta, Söderfors and other large iron and steel works. Especially interesting among the early installations of this class is that at Fagersta, owing to the inclusion of a battery of accumulators intended to take up load variations of 1,000 horse-power for fifteen

seconds without varying the load on the power station by more than 10 per cent. Power at Fagersta is now derived from three distinct hydro-electric stations, having an aggregate capacity of 2,000 horse-power, and the works equipment includes, among others, six motors of from 100 to 600 horse-power for rolling and tube-drawing mills. To the supply of energy to, and the electrical equipment of, the great iron and steel works of Domnarfvet and Sandviken, it will be necessary to refer at some length in a subsequent article.

The electro-chemical industries were, naturally, among the first to avail themselves of hydro-electric energy. As early as 1894 the Stockholm Super-phosphate Works Company erected extensive works for the manufacture of chlorate of potash at Mänsbo, on the Dal River, and placed orders with the G. E. M. Company of Sweden for the supply of generators of about 4,000 horse-power, 320 volts. A few years later another power station of 2,000 horse-power was built at Alby for the manufacture of calcium carbide, and this has since been extended by the provision of a second station, called the Ringdal, in which are installed five single-phase generators, each of 1,000 horse-power, 25 cycles, and generating 10,000 volts directly. Each generator supplies a carbide furnace with power, the current being transformed at Alby down to 45 volts. The advantage of this is considerable, in that any one furnace may be regulated without disturbance of the others. Before leaving the subject of electro-chemical works, it may be convenient to mention that the G. E. M. Company has just completed the installation of a power station of 3,000 horse-power capacity, to be used by the Längeds Company for the production of silicon irons in electric arc furnaces.

HUSKVARNA FALLS, NEAR JÖNKÖPING. HEIGHT, 255 FEET; EFFECTIVE POWER AT LOW WATER, 826 HORSE-POWER

Consequent upon the enormous development during recent years of the sawmills industry, joinery works and



SWARTZENS FALLS, NORRKÖPING, SUPPLYING POWER TO THE TEXTILE AND OTHER LOCAL INDUSTRIES

paper and pulp mills, the demand for waterfalls or power derived therefrom is sensibly increasing. It may be said, indeed, that the first essential to the establishment of any considerable manufacturing business in Sweden is the possession of a satisfactory supply of hydro-electric energy.

Of the electrical equipment, according to the best modern methods, of large paper and pulp mills, the works of the Skarbläcka Company afford an excellent illustration. The power station, in the immediate neighbourhood of the works, has a capacity of 4,000 horse-power, of which about 2,500 horse-power are utilized in the works themselves, while the remainder is transmitted to the city of Norrköping, about 10½ miles distant. As no other than the three-phase system could be entertained for the latter use, it was decided to employ it also in the works, except in connection with the paper machines, the motors for driving which are of direct-current type, supplied from a converter station, converting the three-phase currents to 2 × 220 volts continuous. The power station is equipped with four three-phase generators direct coupled to double turbines, three being of 850 horse-power running at 150 revolutions per minute, while the fourth is of 1,200 horse-power, 115 revolutions per minute. The generator voltage is 800 and the frequency 50 cycles per second. Among the larger motors is one of 1,000 horse-power at 220 revolutions per minute, which is direct-coupled to the shafts of three pumping machines. It is of the synchronous type, and, in order to start it with some load on, a 125 horse-power induction motor is mounted on the same shaft. Other motors of 250 and 210 horse-power drive calenders, and a third, of 170 horse-power, auxiliary machinery in the pulping

MÄNSBO POWER STATION OF THE STOCKHOLM SUPER-PHOSPHATE WORKS COMPANY, 3,750 HORSE-POWER.
GENERAL ELECTRIC MANUFACTURING COMPANY, OF SWEDEN, VESTERÅS

mill, all being built specially slow-running with a view to either direct-coupling or the simplest belt transmission.

Equipments very similar to the above have also been supplied by the Vesteras corporation to pulp mills at Hillringsberg and Jössefors, in south-western Sweden, and Ytterstfors, in Norrland. The extent of the company's operations in connection with the paper and pulp industries may be judged from the fact that the annual production of pulp at the mills equipped by it during the last two years exceeds 125,000 tons.

With a single exception, due to the fact that it dates from a quite early period in the history of the Swedish hydro-electric industry, I propose to postpone more than passing reference to the many supply companies established or projected, with a view to the distribution of electric energy to consumers, large and small, within more or less extensive areas. Among the first undertakings of this kind was the Orebro Electrical Supply Company, which now, from its two power stations—Skramfors and Brattfors—distributes power to the Bofors Steel Works, city of Orebro, Orebro Paper-Mills Company, etc. Its centrals have an aggregate capacity of 7,600 horse-power, and supply at a pressure of 15,000 volts and 50 cycles. That at Skramfors was partly, and that at Brattfors completely, equipped by the G. E. M. Company, of Sweden. The last-named station is remarkable in that it possesses two generators, each of 2,000 horse-power, built for a tension of 20,000 volts direct on the armature, there being in Europe, and, I believe, in the world, only two other machines generating such a pressure.

The following tables will enable the reader to estimate very readily the great development in the use of hydro-electric energy which has characterized Swedish industrial life during the past fifteen years, and promises to be even more pronounced in the immediate future. For the first table, showing the amounts of power derived, respectively, from waterfalls and steam and gas engines, and used in the various industries of the country in the year 1906, I am indebted to Board of Trade statistics:

	Water Motors.		Steam Motors.		Gas Motors.	Electrci Motors
	For Direct Driving in Factories.	For Driving Electric Generators.	For Direct Driving in Factories.	For Driving Electric Generators.		
Food industries, (flour mills, etc.)	53,590	1,150	34,615	5,835	2,637	9,328
Textile industries	14,740	5,274	25,213	4,266	838	9,463
Oil, tar, rubber, etc	889	305	2,120	367	307	313
Tanneries, etc	297	65	1,896	500	714	1,329
Saw-mills, etc	16,034	900	53,006	5,895	364	6,439
Paper-mills	95,382	27,931	15,390	3,945	756	30,074
Joinery works	2,214	160	12,386	1,138	783	2,970
Stone, clay, charcoal, peat	2,347	405	23,005	1,893	1,646	4,325
Chemical works	718	14,725	2,184	350	422	1,079
Machine shops	17,178	6,136	13,453	5,976	4,184	23,207
Electricity stations	......	51,328	......	23,777	1,469	67
Miscellaneous	133	......	393	211	986	2,370
	203,522	108,379	183,661	54,153	15,106	90,964
Iron works	44,212	13,896	9,464	1,510	460	15,710
Mines etc	5,911	......	8,051	......	539	12,099
	50,123	13,896	17,515	1,510	999	27,809
	253,645	122,275	201,176	55,663	16,105	118,773

TABLE SHOWING POWER DERIVED FROM WATERFALLS, AND STEAM AND GAS ENGINES IN THE YEAR 1906

From these figures it will be seen that, of the total power reported to have been generated in 1906, 375,920 horse-power, or 58 per cent., were from "white coal," and 272,405

TOVEHULT POWER STATION OF THE WESTERVIKS ELECTRICITY WORKS COMPANY, 660 HORSE-POWER; EQUIPPED BY THE AMALGAMATED ELECTRICITY COMPANY, STOCKHOLM

INTERIOR OF THE POWER HOUSE SHOWN ABOVE

horse-power, or 42 per cent., from steam and gas engines. Needless to say, reports to hand for the years 1907-8 indicate a very substantial increase in the use of water power by all classes of industry.

The appended tables are compiled from statistics supplied by the office of Electrical Inspection. The first shows the number of licenses issued and permits granted by the government to electric lines up to the close of 1907, the horse-power of the generators, and the length of lines (nearly all overhead) carrying more than 250 volts to earth, *i. e.*, transmitting energy to considerable distances. Of the power referred to, about 95 per cent. is furnished by waterfalls. The second table shows the number of hydro-electric stations in operation in the late autumn of 1908 and the total length of high-pressure lines extending beyond them:

of modern industry the resources hitherto in large measure suffered to run to waste. But militant on the other side have been two circumstances not to be despised—comparative dearth of capital and harassing vested rights and antiquated legislation.

No modern country can compare with Sweden in respect of foreign indebtedness. Her total liabilities abroad, incurred solely for railway development and other profitable works, only slightly exceed £30,000,000. The capital, however, available at home for the prosecution of new industrial enterprises of unusual magnitude is admittedly limited; and to this circumstance we must look for explanation of the prolonged delay in the initiation of many interesting projects for utilizing on a large scale the vast national resources of which this article treats. Yet, rather

	Previous to 1903	1903	1904	1905	1906	1907	Total
Licenses issued	......	7	41	51	62	62	229
Permits for road crossings, etc	176	4	24	45	34	48	331
H.P. of generators	54,000	650	10,200	6,500	20,840	17,000	109,190
Miles of lines	515	19	135	125	280	275	1,349

TABLE OF LICENSES ISSUED, ETC., BY THE GOVERNMENT UP TO THE CLOSE OF 1907

No. of hydro-electric stations	220*
H.P. of generators	176,000
Miles of high-pressure lines	1,750

* Exclusive of factories, etc., having hydro-electric plants on their own premises.

TABLE OF HYDRO-ELECTRIC STATIONS IN OPERATION LATE IN 1908, AND TOTAL LENGTH OF HIGH-TENSION LINES EXTENDING BEYOND THEM

Noteworthy, and even remarkable, as is the development indicated by the foregoing statistics, it by no means represents all that might reasonably have been expected. The Swedes are ambitious of occupying a higher position among the industrial nations than they at present hold, and possess natural gifts and technical training and attainments well calculated to aid endeavours to this end. They fully appreciate the value of the wealth scattered over their country in the form of water systems, and, as already suggested, need no imported brains to subject to the requirements

than directly invite foreign financial co-operation, the promoters of electrical supply companies and other industrial undertakings continue to pay to their bankers interest at the rate of 6 to 6½ per cent. for needful advances, represented probably in large degree by bills held abroad. To persons acquainted with Sweden, and not unmindful of the extraordinary flotations emanating from other countries which from time to time see the light and presumably dazzle the imagination of the unwary, the situation savours of paradox, to say the least.

The existing laws in relation to

NÄÄS POWER STATION OF THE MOTALA RIVER POWER SUPPLY COMPANY, 1,800 HORSE-POWER, 20,000 VOLTS. GENERAL ELECTRIC MANUFACTURING COMPANY, VESTERÅS

water rights are not only extremely complicated, but also admittedly unfitted to present conditions. It is, consequently, not surprising to hear on all sides a strongly expressed hope that the Riksdag will, at an early date, devote serious consideration to the question. The importance of the latter was recognized by the government in 1906 by the appointment of a committee to prepare suitable legislation.

Proprietarial rights in waterfalls and rapids originally followed possession of the adjoining land; that is to say, the owner on either side could dispose of half the width of water. Consequent, however, upon division of the larger estates, water rights also have been subject to partition, and are now often found associated with ownership of real estate situated far from the banks. Another frequent source of trouble preceding agreements for the purchase or electrical equipment of a waterfall is the fact that "width" and "power" are far from synonymous—that the head often varies considerably from point to point.

A peculiar regulation is the so-called "kungsadra," by which is meant one-third of the width of a river where deepest. According to the old law, this "kungsadra" must be kept open on all important waters in the public interest, for fishing, timber-floating, etc. The government, however, now possesses power to allow, on special conditions, the building of dams across "kungsadra." Such permission, as a matter of fact, is seldom applied for, involving, as it does—and the same may be said generally of disputes regarding water rights—long and costly procedure in the courts and before administrative authorities.

The law of 1902 affecting electrical undertakings is framed in the most

liberal spirit as regards licenses, subsequent regulation and interpretation of the phrase "public utility." Such an undertaking can, for instance, obtain from the government without difficulty the right to expropriate ground for the erection of transmission lines, no other obligation being imposed than the payment of suitable indemnity for the land occupied.

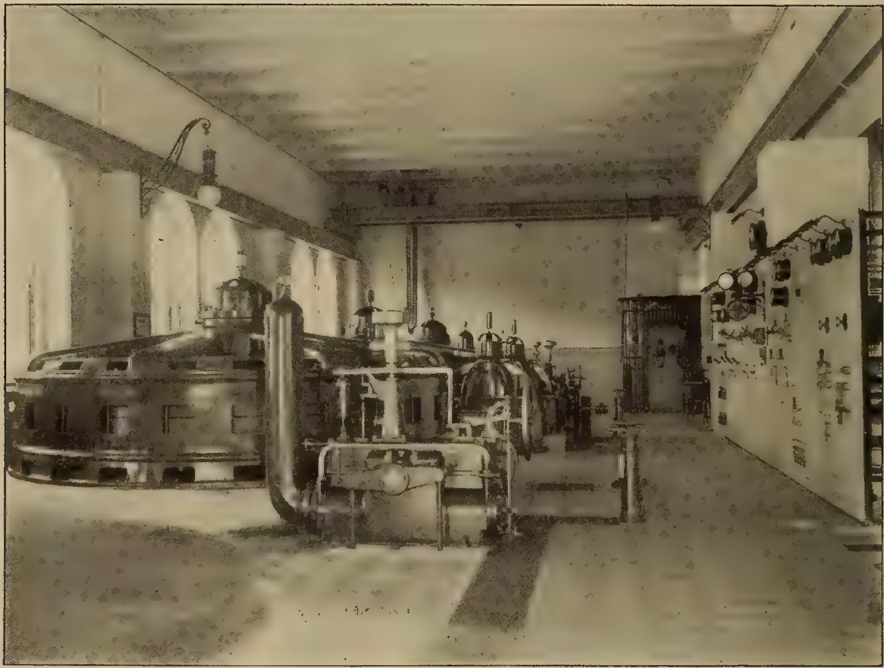
Government licenses are required for all lines for which power to expropriate is given, and for all overhead lines carrying a pressure of more than 250 volts to earth and extending beyond the owner's land. Such licenses, which are granted for a period not exceeding forty years, contain stipulations for ensuring the safety of the public and the undisturbed working of railways, telephone lines, etc.; and where no license is needed permission must be obtained from the government for crossing public roads and railways. Licenses and permits are granted free of charge.

For damage to person or property caused by electric current the owner of the generator or transformer is primarily responsible, all claims for indemnity being determined by common law. It is interesting to note that during the six years the law has been in force not a single case of the kind has been brought before the courts. Compensation to workmen injured in the discharge of their duties is, of course, regulated by special legislation.

When the law of 1902 came into force the government issued general technical regulations — subsequently supplemented in certain details by the Board of Trade—applicable to all electrical undertakings, whether licensed or not. Inspectors, of whom there are now four, were also appointed, to report upon accidents caused by electricity and supervise all high-voltage work and installations deemed specially dangerous.

All long-distance transmission lines are built on the three-phase system,

NYKROPPA POWER STATION OF THE STORFORS IRON AND STEEL WORKS COMPANY, 750 HORSE-POWER, DIRECT CURRENT, EQUIPPED BY THE AMALGAMATED ELECTRIC COMPANY, STOCKHOLM



FRYKFORS POWER STATION. INTERIOR VIEW, SHOWING DYNAMOS, GOVERNORS AND SWITCHBOARD

FRYKFORS POWER STATION OF THE VERMLANDS COUNTY ELECTRICAL SUPPLY COMPANY. HEIGHT OF WATERFALL, 27 FEET; DISCHARGE, 882 CUBIC FEET PER SECOND; 4,000 HORSE-POWER; VOLTAGE, 34,000. GENERAL ELECTRIC MANUFACTURING COMPANY OF SWEDEN, VESTERAS

and, excepting the State enterprise at Trollhättan (25), with a periodicity of 50 revolutions per second. Heretofore the lines have been hung with short spans on wooden poles, but all later undertakings have adopted steel towers, with spans of 600 feet or more.

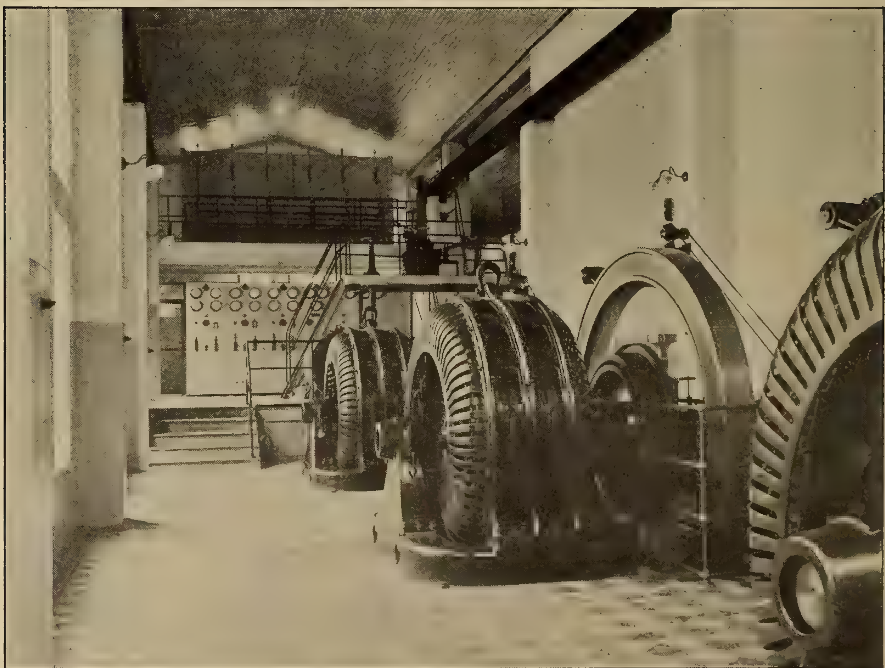
The selling price of waterfalls varies very considerably, being dependent not only upon the amount of energy obtainable, but also situation, adaptability for utilization, possibility of water regulation and other factors. A fall, for instance, which commands the right of regulating other waters, is esteemed far above the value of its own energy. During recent years many conveniently situated falls have changed hands at £3 per horse-power on the turbine shafts at low water; for others, owing to special circumstances, double that price has been paid; while falls less accessible or removed from centres of population have been sold at the rate of 6 shillings per horse-power, and even less. From this it will be seen that, for chemical and other industries which require large amounts of cheap power and need not concern themselves much about the location of their works, Sweden offers great advantages.

Apart from the value of the waterfall itself, the cost of installing a hydro-electric plant appears to vary between £3 10*s*. and £6 per kilowatt. Electrical energy in large quantities is usually supplied at from 24*s*. to 38*s*. per kilowatt and year, but in a few cases the price falls as low as 11*s*.

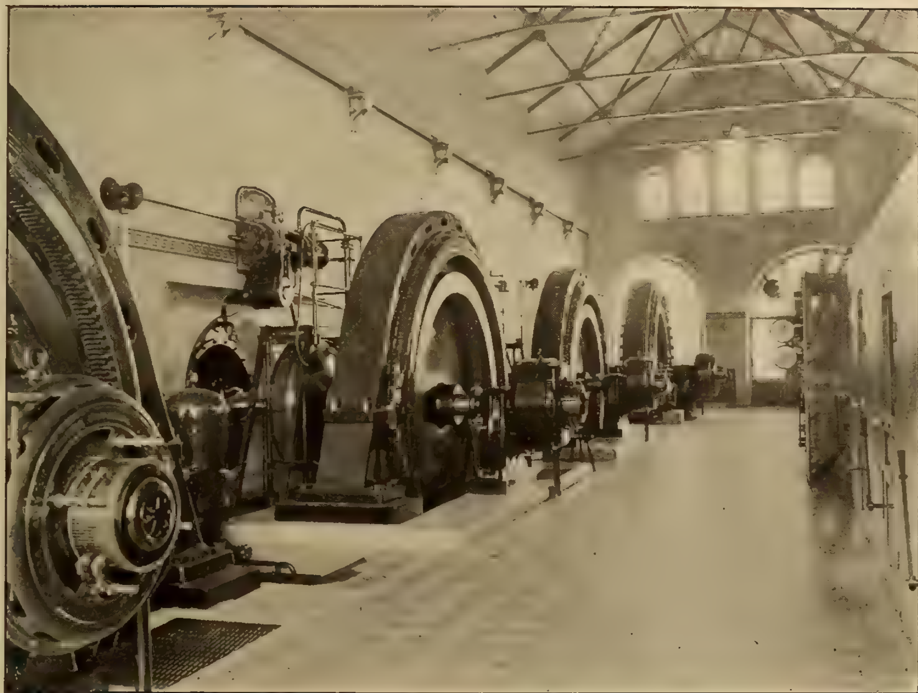
HAMMARFALLET POWER STATION OF THE HELLEFORS WORKS COMPANY (IRON AND STEEL WORKS, SAW AND PULP MILLS), 460 HORSE-POWER, EQUIPPED BY THE AMALGAMATED ELECTRIC COMPANY, STOCKHOLM

One of the most obvious characteristics of the Swedes is their intense and deeply-rooted love of Nature, an attachment so instinctive and widespread that they themselves do not appear fully conscious of its existence. It is, consequently, with no little surprise that a student of their

JÖSSEFORS FALLS AND POWER STATION; FALL, 24.5 TO 26 FEET; DISCHARGE, 777 CUBIC FEET PER SECOND, MAXIMUM



INTERIOR OF JÖSSEFORS POWER STATION, 1,800 HORSE-POWER, 7,000 VOLTS, EQUIPPED BY THE GENERAL ELECTRIC MANUFACTURING COMPANY, VESTERÅS

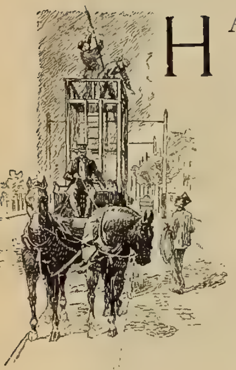


POWER STATION OF THE SKÄRBLACKA PAPER AND PULP MILLS COMPANY, 4,000 HORSE-POWER, 15,000 VOLTS. GENERAL ELECTRIC MANUFACTURING COMPANY, VESTERÅS

recent industrial development learns of the complete absence of laws or administrative regulations concerning the preservation of natural beauties. The government has in view, I understand, a measure providing for the protection of characteristic and peculiar features in respect of flora, fauna and geological formations; but of special legislation, prompted by æsthetic considerations, affecting the utilization of waterfalls, there seems small likelihood, or, as some may regard it, danger. The question is rightly regarded as a delicate one, affecting the free disposal of private property. The State, however, in its capacity of waterfall-owner, may be expected to set a good example; and it is doubtless wise, in view of the characteristic to which I have referred, in abstaining from the initiation of grandmotherly, and possibly quite needless, law-making.

INTERURBAN RAILWAY DEVELOPMENTS IN THE UNITED STATES

By George Ethelbert Walsh



HALF a century ago, when the steam railroads entered upon their campaign of revolutionizing the trade and commerce of this country, the only possible competitors they had in the field were the canals; but the development of waterways never reached a point where they seriously interfered with the traffic of the railroads. The appearance of another competitor on the scene, which is now running a neck-and-neck race with the steam roads, compels more serious attention, and in many parts of the United States the railroads have actually capitulated to this new but lusty rival. In other sections they have resorted to the old-time tactics of trying to steal the enemy's thunder by electrifying many of their branch lines and feeding systems, or by outright purchase of parallel electric roads.

Interurban trolleys have made greater progress in the past few years in America than the steam railways, and they have developed rapidly toward a common aim with their old competitors. So long as the electric roads restricted their field to the towns and cities there was no reason for opposition from the steam lines to their growth. Within a decade they performed for the cities what the railroads had accomplished in a longer space of time for the whole country. They made travel easy, cheap and practical. The invasion of the immediate suburbs of the cities by the electric railways was not at first seriously looked upon with disfavor; but when these lines were extended, and connecting systems began to parallel the steam railroads and unite in continuous sections, there was good occasion for alarm. Then came the birth of the fast interurban trolley and the freight-carrying electric service.

The power to carry merchandize was the most serious inroad upon the field and prerogatives of the railroads. In the New England States the steam lines fought in nearly every Legislature the applications of the electric roads for freight-carrying charters, and for a time they were successful in blocking them. But modern conditions demanded the innovation, and trade could not long expand in many suburban sections without some such improvement in the carrying facilities of the country. The interurban trolley lines contented themselves at first with small express packages and light merchandise, and then they extended their freight department to include perishable articles from the farms, and finally they have undertaken the transportation of heavy freight of a character that cuts seriously into the profits of the steam lines.

Trade conditions are improved or retarded in every country or section in proportion to the facilities of transportation furnished by the roads, and it is quite evident that, in extending their lines into new and old regions, the interurban electric railway is fast producing revolutionizing conditions. At first the development

of the electrics followed the beaten path. That is, they contented themselves with merely paralleling the existing steam roads or following well-traveled country or post roads from town to town. This brought them into active competition with the railroads and engendered a bitter rivalry. But the new policy of the electrics is to cut out lines of their own, acting independently of existing roads. They are now entering upon this new departure with avidity and remarkable success. They are establishing pioneer lines in sections of the Middle and Far West United States where steam roads have never been built, and where in all probability they would not be built for decades. The effect of this forward policy has been to give a new incentive to trade, and to develop rapidly great sections of the country.

If the electric railway developments simply took business away from the established steam lines, their usefulness might prove less valuable than it is; but they do more than this—they make new business and stimulate new trade and commerce. In the sections of the country where they have been established as freight carriers for a number of years the volume of trade and freight has increased from 10 to 100 per cent. For small freight and express merchandise, the interurban trolley line has become indispensable in the rural districts both because of the reduced carrying charges and the quickness of delivery. Goods can be ordered one day by telephone and be delivered the following morning by trolley. Stores which formerly had to carry large stocks of miscellaneous articles depend to-day more upon the city jobbers and wholesale houses for quick delivery of anything needed via the express trolley. Many wholesale firms make it a business to hold an assorted miscellany of goods for this kind of trade in crated form for immediate shipment. Time and expense are saved thereby. The country or village store takes an order from a customer, and telephones to the jobber or wholesaler to deliver the goods direct to the purchaser; but the bill is mailed to the country store, and the retail merchant gets his regular commission. There is a saving of one cartage by this method, as delivery is made from the wholesaler direct to the consumer.

The interurban trolley lines tap the various towns and cities along their routes and connect with the city electrics or the smaller lines which run in all directions to small places. At the various intersecting points freight-sheds or houses are built, and merchandise can thus be quickly and expeditiously shipped to all parts of the country. The farmer who, a few years ago, had to drive five or ten miles to the nearest railway station, now finds the accommodating trolley car stopping almost at his door. He can receive express matter and light merchandise daily within a few hundred yards from his house, and he can ship milk, eggs and farm produce, billed through to any distant or near-by point, without much trouble. In the busy season on the farm this is of the utmost importance to him, for his teams and men are then needed for other purposes than driving to a distant station to ship produce.

In Ohio, Indiana, Michigan and other Middle Western States the interurban trolley has been brought to its highest development, although in parts of New England and New York the development of the systems has been almost equally phenomenal. In some cities, such as at Cleveland, the interurban trolleys have union freight stations, where baggage and merchandise are transshipped to all parts of the country. The freight and express trolleys run mostly between midnight and the early morning hours, when the passenger traffic is almost at a standstill. A few freight cars are run over the busiest lines in the daytime; but at midnight the freight has been piled up for ready shipment, and it is then immediately rushed

out in all directions. At one of the large freight houses of an interurban trolley the scene after midnight is a busy one. The night shift of freight handlers come on duty about eleven o'clock, and all through the small hours of the night they rush through the work that has piled up through the day. As a result of this system, freight delivered in the afternoon is, in most instances, deposited at the different freight sheds scattered all along the route by early morning. The farmer or suburban resident wakes up to find his express packages and light merchandise waiting for him at the nearest delivery shed.

The development of the freight traffic has paid so well that its expansion is increasing rapidly. At first it was considered a somewhat doubtful expedient. For one thing, it was feared that it would disarrange the passenger service seriously; but this has not proved true in any instance. Another question was whether it would not prove too severe a strain upon the cars and tracks. But larger cars and heavier tracks and roadbeds have been constructed to meet the new conditions. The freight and express department of many an electric railway has saved it from bankruptcy in the past five years. Where the passenger service could not pay fair interest on the investment the freight and express service turned the scales and made the road pay. On some of the Western and New England roads running through sparsely settled regions, the freight and express service pays better than the passenger department. Besides stimulating the farmers to more frequent shipment of perishable goods to the towns and cities, the interurban trolley has spread the building of factories and manufacturing plants over a wider area. A great many of these plants have been induced to locate in the country by reason of the superior freight accommodations provided by enterprising electrics. The price of land is much cheaper for the factories in the country districts, and, if assured of reasonably regular and cheap freight rates, the manufacturers find it profitable to build in new sections. This, in turn, has had a tendency to build up new communities, and the trolleys have reaped a double advantage from the passenger traffic.

Of course, in the establishment and growth of interurban trolley systems the passenger traffic has received the greatest attention, and this in some instances has assumed enormous proportions. In Indiana during 1907 more than 125,000,000 passengers were carried by the interurban trolley lines, and the twelve electric railways which meet in Indianapolis carried to and out of that city more than five million passengers. The freight tonnage of these lines also amounted to over 100,000 tons. In Indiana and Ohio the trolley systems practically cover every part of the States, and it is possible for passengers to reach any small town or village or almost any farmhouse by electric cars. Most of these roads charge at the rate of two cents a mile for a single fare in Ohio, and from one to two cents in Indiana and Michigan. In all cases, however, where paralleling a steam railroad, the charges of the trolley lines are a little less than the rates fixed by their older competitors. For instance, from Toledo, Ohio, to Dayton, the round trip by steam roads is $6.05, but by trolley line it is $5.25. The differences in charges, however, would not attract many passengers if the time was not also made approximately the same.

The interurban trolleys have increased their speed steadily, and also their long runs without stopping. One can travel on the electric railway from Marion, Ind., to Anderson—a distance of 72 miles—with only two stops; or from Indianapolis to Fort Wayne—a distance of 138 miles—in four hours and forty minutes. This limited and fast service is obtained by running special expresses at intervals, with many more frequent locals between, which stop

at about every mile. Between Dayton and Toledo there are six limited trolley expresses a day, which make the total run of 162 miles in six hours or less. These interurban expresses run on the tracks of several different lines. The various systems are co-operating so that local and through trains can be run without a hitch, and in this way they are rivaling the steam roads in long hauls.

The modern fast interurban trolley car is a mammoth affair compared to the type in vogue five or ten years ago. A car of the better class is from 50 to 60 feet in length, and it possesses all the equipments and luxuries of a steam train. They contain baggage departments, toilet rooms and buffet compartments. Thev have outside seats for summer travel, well protected in front, and have closed compartments for winter traffic. On some of the lines, such as the Lake Shore Electric, the cars are run in trains of two or three; but unless the traffic warrants it they are operated singly on most of the roads.

The interurban electric railway companies issue all sorts of tickets to encourage travel, such as regular mileage books, family trip books, school children's tickets, workingmen's tickets, and regular daily commutation books. They have, in fact, borrowed from the steam railways all that is considered the most successful and then inaugurated many improvements of their own devising. It is possible to travel four and five hundred miles by these tickets in one direction, and the time required is about the same as by steam cars, or even less.

The development of the trolley system is just beginning, and it will not be long before fast trips can be made by these systems from Chicago to New York or to Portland. These trips may be made to-day, but in a roundabout way and by slow degrees. There are not connecting trolley expresses put into service which makes such long service practical. But how soon this may all be changed no one can say. The leaders in the trolley improvement promise that within a few years it will be possible to travel between all the chief cities of the United States as fast by the electric railways as by steam. Tickets will then be sold through from New York to Chicago, or to Washington, or to Portland, Me.

The interurban trolley has thus entered upon a stupendous campaign, and the results must be of a most revolutionizing character. If the steam railways are to retain and hold their traffic, they must meet the new conditions progressively and intelligently. In such States as Indiana and Ohio the trolleys have already cut down the railroad passenger service nearly one-half, and in other sections the stupendous growth of the service is making great inroads into the steam lines.

Naturally, the railroads are retaliating by making improvements of their own. In many parts of the United States the steam lines are adopting electric service for a part of their passenger traffic, and in some instances they are using gasoline-driven trains as an offset to the trolleys. Electric trains have proved good feeders for the railroads in densely populated regions, and gasoline-driven engines are excellent substitutes in places where the traffic is light. This new era of transportation has passed out of the experimental stage into an actually demonstrated condition. The railroads have spent millions in the last few years in electrifying branches and suburban lines to compete with the trolley systems; and this expenditure, averaging something like $25,000 a mile for construction and equipment, has all the promise of profitable investment. In many parts of the Western United States the steam roads have introduced gasoline-driven cars as formidable competitors of the interurban trolleys, and these are making excellent headway where traffic is comparatively light.

The first gasoline motor car was run on the Wurtemburg Street Railway in 1893, but this was a very crude affair in comparison to those adopted in America. On the Union Pacific Railroad the gasoline-driven cars have been in operation for a number of years, and they have traveled from Omaha, Neb., to Portland, Ore., and from Omaha to New York. On the Santa Fé lines the cars have run 18,000 miles without repairs, and the heaviest of them are able to run a mile a minute and maintain under ordinary conditions at least 45 miles per hour. The gasoline cars will seat 75 people, and they provide as much comfort and luxury as any cars of the steam roads or electrics. A ventilation system is provided which makes the air of the interior as free from odours and dust as possible.

These cars are now making daily trips between Houston and Galveston, Tex., and at Omaha, Neb.; Los Angeles, Cal., and at Portland, Ore. Between Kearney and Callaway, Neb., the gasoline cars make daily trips over the Union Pacific line—a distance of 65 miles—and also between Leavenworth and Lawrence, Neb.—a distance of 68 miles. They require only a motorman and an attendant, and trailers can be added as needed. The railroads experimenting with gasoline-driven cars have found that, for comparatively short runs, and where the traffic is light, they are the cheapest means of transportation; but when the traffic increases the steam propulsion is more profitable. According to the estimates of railroad engineers, it costs 24 cents a mile to operate a local steam train, consisting of a locomotive and two cars, including expenses for labour, repairs and cleaning. The cost of operating an electric motor car, with one trailer, under similar conditions, averages 18 cents, and a gasoline motor car, with a trailer for passengers, baggage and express, is about 15 cents per mile.

The steam railroad companies, in their effort to meet the competition of the interurban electric trolleys, have been experimenting not only with the gasoline-driven engine, but with steam motor cars and electric motor cars in which gasoline is merely used to generate electricity, and the propulsion power of the motors is derived from the latter. The Erie and Canadian Pacific Railways have both tried the steam motor cars, with more or less success, and the Delaware & Hudson Railroad has successfully experimented with the gasoline-electric motor car. The railroads from one end of the land to the other have thus been driven by the trolleys to try new methods of meeting the fierce competition of their lusty young rival.

Ten years ago few believed that the motor car of any description could enter successfully into competition with the steam roads in long hauls; but the trolleys have steadily increased their hauls, until to-day it is admitted by the railroads that this competition is possible, at least up to 300 and 400 miles. This no longer restricts the electric system to suburban traffic and comparatively short runs. According to the figures of the chief engineer of the Southwestern Wisconsin Interurban Railway, the cost per mile per car over a distance of 300 miles of track, making six round trips daily, is decidedly in favour of the electric motor car. He places the cost for such a long haul at $73.29 for steam, $54.70 for gasoline, and $51.36 for electric cars. On the other hand, where the traffic is light, and only one round trip is made a day over a track of 50 miles, the relative cost for steam, gasoline and electric is placed as follows: $19.53, $18.20 and $38.31. The electric line must, therefore, have moderately heavy traffic and frequent runs to make it profitable. This is partly owing to the expensive cost of the initial equipment of the line.

All of these conditions and experiments prepare the way for the rapid changes being made in transportation in America. Conditions are favourable to-day for the electrifica-

tion of the whole New York, New Haven & Hartford system and for a large part of the Eastern division of the New York Central. The Erie is likewise so situated that a good part of it can be economically electrified, and 34 miles on the Erie division has already been equipped for electric propulsion, drawing its power from Niagara, some 70 miles away. In Italy and Switzerland the electrification of the roads has carried out practically these calculations made for American roads. But the electrification of such a line as the Great Northern throughout its whole length appears to be an unprofitable project, at least for the present.

This new era of transportation is bringing about so many changes that the very rapidity of it causes trouble. The railroads being fully aware of the growth of the interurban electric lines, and feeling no longer safe for their comparatively long hauls and express and light freight service, must adapt themselves to the new methods; but while they are making tremendous sacrifices in some sections to head off the competition through the electrification of their lines, they are experimenting with new methods in other States and regions to ascertain in advance every possible means of improving upon the trolley system. The Union Pacific Railroad has thus scored a complete success in equipping many of its small branch lines with the gasoline motor, and even the Great Northern Railway is equipping some of its feeders with similar cars. While the electrification of the New York Central and New York, New Haven & Hartford suburban lines is the most costly and stupendous undertaking of any of the steam roads to meet the trolley competition by new methods, a dozen other important railroads are bringing their equipment up to date in various sections. The interurban trolley line has thus inaugurated a system of railroading which must advance with the times and become in the near future a great factor in the transportation problem.

In Indianapolis, for instance, the interurban trolley has proved such a disturbing factor in the railroad situation that the freight and passenger service of the railways has been cut down nearly one-half in the last five years. More than 400 trolley cars are sent in and out of that city daily to the nearby and distant cities, including many of the fast flyers which run on as quick time as the steam cars.

But the interurban trolleys are not always antagonistic to the steam lines. In many parts of the country they have proved of great help to the railroads. They act as feeders to them and supply them with more freight and passengers than they could otherwise have carried. They collect freight from the rural districts, and, through a working agreement, hand their shipments over to the steam lines for long-haul transportation. Ten years ago none of the steam roads would enter into any freight or express agreement with the interurban trolleys for the handling of merchandise, but to-day nearly all of them are willing to do this. In fact, there is considerable competition between some of the rival railroads entering a city to co-operate with the trolleys. They have found that the traffic is of sufficient volume to make it profitable to handle it for long hauls. In many instances the trolleys have a working agreement to run on the tracks of the railroads for the speedy transshipment of freight and express.

Not a few of the progressive managers of the electric lines claim that there is no rivalry between their systems and the railroads; but, on the contrary, a co-operative exchange of transportation that is of mutual benefit. They give more than they take away from the steam railroads. If this should be proved an established fact the growth of the interurban trolleys would be a double blessing. They would complete the chain of roads which extend from sea coast to sea coast, and bring every community into closer touch

with the large cities. They have certainly helped the small community and made rural life more pleasant and satisfactory. They have revolutionized village trading and given the small merchant almost the same advantages enjoyed by the city business man. City and country are welded together by the interurban trolley, and the country becomes the feeder to both small town and large municipalities. Trade and commerce flows more easily and rapidly through these thin avenues of exchange, which criss-cross the country like the fine threads of a spider's web. Country amusement parks are built up to furnish outing parties from the cities with recreation; real estate of the suburbs is enhanced, and thousands of people are induced to reside in the country who never before dreamt of it. The redistribution of the population by the trolleys is not the least of the important results produced.

THE MODERN COTTON SPINNING FACTORY

By W. H. Booth

II. THE OPERATIONS OF CARDING, COMBING, DRAWING, SLUBBING AND ROVING

In the January issue the study of the work of the modern cotton-spinning factory was begun, that instalment of Mr. Booth's paper dealing with the general subject, including the raw material, and the preliminary operations of its preparation. The present portion of the article discusses the further treatment of the material and the machinery required, to be followed by a concluding article upon the final processes.—THE EDITOR.

CARDING.

The laps from the scutching room should possess three special qualifications, namely, correct weight per unit of length, even thickness over their whole surface, and even, smooth edges. The first is attained by adjusting the weights fed to the first scutcher, or by varying the lattice speed of the second scutcher. Even thickness is a product of correct working of the scutchers, and even edges result from the same cause and from care in transporting laps to the carding engines. It is therefore desirable that the output of the cleaning department shall be such as to give proper time for adjustment and repairs in order that the cards may not go short of laps.

Cotton is carded to remove short and imperfect fibres and any remaining bits of husk, leaf, or even sand. Carding opens up and separates each individual fibre and, to some extent, begins the process of laying the fibres parallel.

There are two main varieties of carding engines, roller and flat, Fig. 1.

In the roller card, only employed for coarser counts and for waste carding, a large cylinder A with a surface speed of 1,600 feet per minute and covered with wired cloth as in Fig. 1, the wires being bent forward in the direction of rotation, picks up fibre from a smaller roller K, known as a licker-in. This roller has clothing of heavier wire and has a surface speed of half that of the main cylinder. This roller combs down the fibre entering from the small fluted feed roller Q, which draws in the lap O, and from this licker-in the fibre is combed off by the upward quicker running cylinder. Round the cylinder several pairs of rollers are set in place of the flats shown in Fig. 1; one of these, with its teeth set the reverse way from the teeth of the cylinder, practically touches the cylinder and revolves, so that the surface moves in the same direction as the cylinder surface, but only at some 20 feet velocity per minute.

The fibre is caught up by this roller and is well combed in the process of transfer. The other roller, which runs twenty times as fast and in the same direction, has its teeth inclined forward in the direction of motion and strips off the fibre from its slowly-moving companion, and is in turn itself stripped by the cylinder which carries the fibre again to the roller, the clearer being so placed as to cause the fibre to pass as many times as it can succeed in doing from cylinder to roller, clearer, cylinder, and roller again. The action appears fortuitous, but an inspection of a running engine shows that each succeeding pair of rollers and clearers presents a more even appearance, less dotted with partly carded fibre.

Apparently the well-carded stuff does not get taken up by the slow roller and is carried on to the doffer R, a slow-moving large cylinder on which the teeth are set opposite from the

main cylinder teeth and its surface moves with the cylinder surface, but at a speed of only sixty to seventy feet per minute. The cylinder parts with its load of carded fibre to the finer wires of the doffer, and a rapidly-reciprocating short-toothed steel comb *S* combs the fibre off this doffer cylinder upon a smooth plate. The vibration is 600 to 1,000 per minute. The smooth plate on which the stripped fibre falls has tapering vertical walls which close in the filmy web of fibre, and this now enters a trumpet cone and passes between rollers which condense it. It travels thence as a band between other rollers, which pass the sliver through another trumpet on a revolving plate *V*, which delivers the sliver into a tall tin cylinder *W*. The discharge orifice of the horizontally-revolving plate describes a circle of one-half the diameter of the tin, and as the tin cylinder rotates slowly on its axis the sliver is coiled neatly all round the tin.

The lap of cotton, which is fed in at about 9 inches per minute, is spread over a length of perhaps 18,000 inches of cylinder. This thinly-spread fibre is crowded upon a less length of roller surface and again expanded upon the greater length of cylinder surface and so on as it travels from roller to cylinder again and again. Then on the doffer the 9 inches is gathered into a surface length of eighty to one hundred times as much and the lap has received its first draw-out. The carding is an operation of great agitation and bits of husk and leaf are loosened out. The film produced should appear regular, clear and free from cloud when held to the light. The rollers above the can-coiler slightly draw out the sliver as it is delivered from the first condensing rollers on the doffer plate. This is only a slight draught, but it keeps the sliver taut and helps to parallel the fibres. But there is still very little parallelism of the fibres, and such yarn as could be spun from such curled fibres would be thick, rough and fuzzy. Truly parallel fibres are secured by the operation of drawing in the case of coarse yarns, while, in the spinning of finer yarns, there is an intermediate additional combing process which again rejects some material as waste. The carding engine also rejects fibres to waste. This waste consists of the shorter fibres flung off from the rapidly-rotating cylinder by centrifugal action and deposited below the cylinder in the base of the casing. This waste is known as fly, and it is sold to spinners of coarser counts, the fly from good Egyptian cotton being superior to the cotton bought in the raw state for coarse counts. But the roller car is almost obsolete—entirely so for fine counts—having been displaced by the revolving flat card, as illustrated in Fig. 1. In this machine there is the same large cylinder, doffer and licker-in, but in place of the rollers and clearers there is a traveling band of closely-linked flat bars *B B*, covered with card cloth and traveling very slowly round the upper part of the cylinder on the side frames of the machine, which are carefully turned concentric with the cylinder. The chain of flats in an endless band turns away from the cylinder at *M* as they approach the doffer cylinder and pass back, a few inches above the working flats, to the cylinder near the licker-in at *N*. As the flats, which are only 1⅜ inches to 1⅝ inches in width, turn up round the carrier roller, they are stripped by a reciprocating comb *F* and cleaned of the fibre that sticks to them by means of a slowly-rotating helically bristled circular roller brush *G*. This stripped fibre is waste, and the cleared flat starts again at the cylinder as it reaches the carrying roller at that point of its cycle.

The rate at which cotton passes through the carding process is slow, an engine 45 inches wide on the wire face only turning out from 5 to 7 pounds of Egyptian cotton per hour for counts of 60's, while for low counts of 10's to 20's, 15 to 18

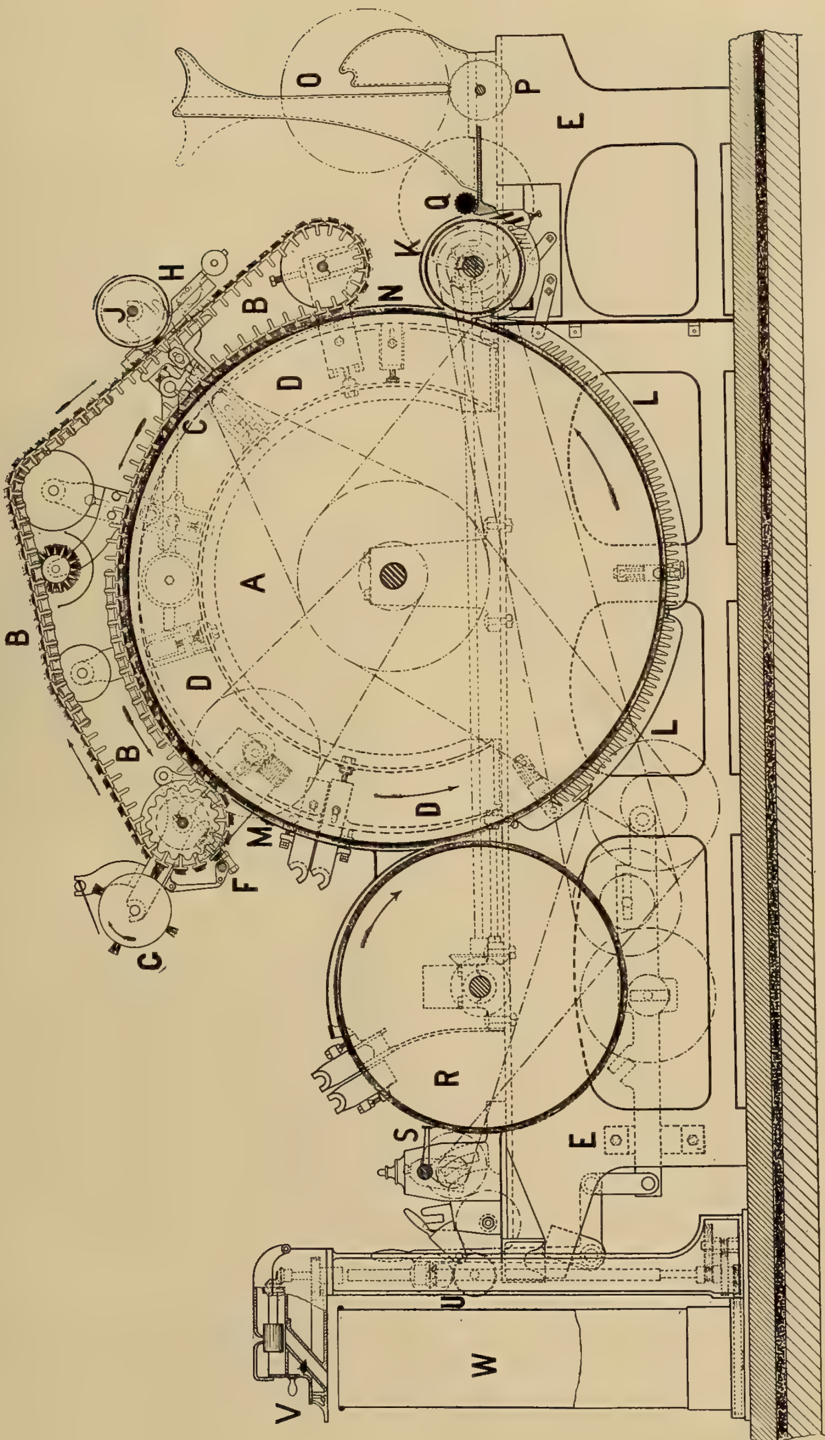


FIG. 1.—PATENT IRON REVOLVING FLAT CARDING ENGINE. PLATT BROTHERS & CO., LTD., HARTFORD WORKS, OLDHAM

FIG. 2.—BACK OF CARDING ENGINE FLAT

pounds may be carded per hour. The number of cards is therefore large, especially in a coarse-counts mill.

As an instance of one of the many improved details of cotton machinery generally, there may here be cited the slow-motion driving of the doffer cylinder, whereby, if the web or sliver has broken down, the doffer and the feed rollers are both thrown into slow gear while the attendant pieces up the sliver. The slow motion is given instantaneously by releasing a lever, and it automatically discontinues itself after sufficient time has elapsed to effect piecing up. This prevents the big delivery of fleece during piecing up, which results in considerable waste. The wired cloth with which carding cylinders and flats are covered is made of varying fineness and length of wires.

Wires are fixed into the cloth in the form of two pronged staples, and each prong is bent at an angle at about a fourth of its projection from the cloth, this causing the wire to point forward and not to stand out radially from a clothed cylinder or vertically from a flat. There may be 250 staples in a square inch of cloth or 500 points of wire. The back of the cloth is thus nearly covered by horizontal lengths of wire forming the bases of the staples, and the wire projects about ⅜ inch from the face of the cloth when new. As many as 108 or 112 flats go to each engine. The points of the wires on the flats, as well as on all other clothed surfaces, are ground from time to time by means of long emery rollers, which rotate rapidly with a quick to and fro end movement also. It is essential to grind all cylinders truly cylindrical, and to grind the flats from the working face which slides upon the concentric frame. The roller *J* is this emery roller. The flats are so set that their wires just fail to touch the wires on the cylinder. This can be ascertained by means of a thin "feeler" gauge of flat steel. Speaking generally, the best class of cotton will require 50 per cent. more wires per square inch than will the lowest classes.

The clothing of carding-engine

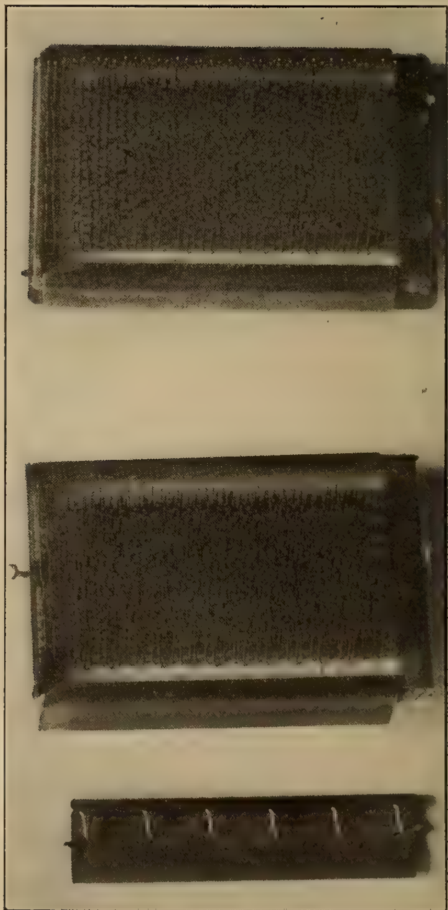


FIG. 3.—SHORT SECTION OF CARDING ENGINE FLATS, SHOWING CLOTHING AND HOLDING CLIP

cylinders and flats is done with a sort of rubber canvas, in which are set immense quantities of wire points. This wire is of hardened and tem-

FIG. 4.—SAMPLES OF CARD WIRE CLOTH FOR STRIPPING AND BURNISHING

pered steel. In order to keep the wire perfectly bright, the processes of hardening and tempering are performed in a vacuum, thus keeping the wire away from oxygen. Messrs. Sykes Bros., of Lindley, Huddersfield, whose production is illustrated in this article, employ an electrical process of heating and are able to produce a perfectly smooth, bright wire. Card clothing is made on long bands 1½ inches wide for doffers, and 2 inches wide for the main cylinders, and it is wound tightly in

spiral form and nailed into wooden plugs let into the face of the cylinders. The machinery by which card clothing is made is very ingenious. Many of these machines run at 400 revolutions per minute, and at each revolution the cloth is pricked through in two places, a piece of wire is cut off from a reel, bent into a two-pronged staple, inserted through the two pricked holes and bent to the correct angle, so that when the clothing is attached to the cylinder the wires point forward at a small angle. After the cloth is in place, the points of the wire are all ground to one height and to a needle point. A bit of card clothing is really a work of art, and a beautiful piece of repetition work. The production of a carding engine per hour is only a few pounds of carded cotton, so that many millions of points of wire come into action in the process of carding each pound of fibre, the essence of good carding being the absolute separation of every fibre, and the removal of all curls or matted fibres. A rough parallelism is given to the fibres, and dust and short fibres are thrown off.

Among the many modern improvements in cotton machinery are the stop-motions at many points, which cause a machine to stop if the sliver or end breaks, and the many safety checks which prevent the door of a gearing-box from being opened when a machine is at work, and when the box is open or some cover is open or removed, also prevent a machine from being set in motion until such cover is safely put back into place again. These safety devices obtain the approval of H. M. Inspectors of Factories.

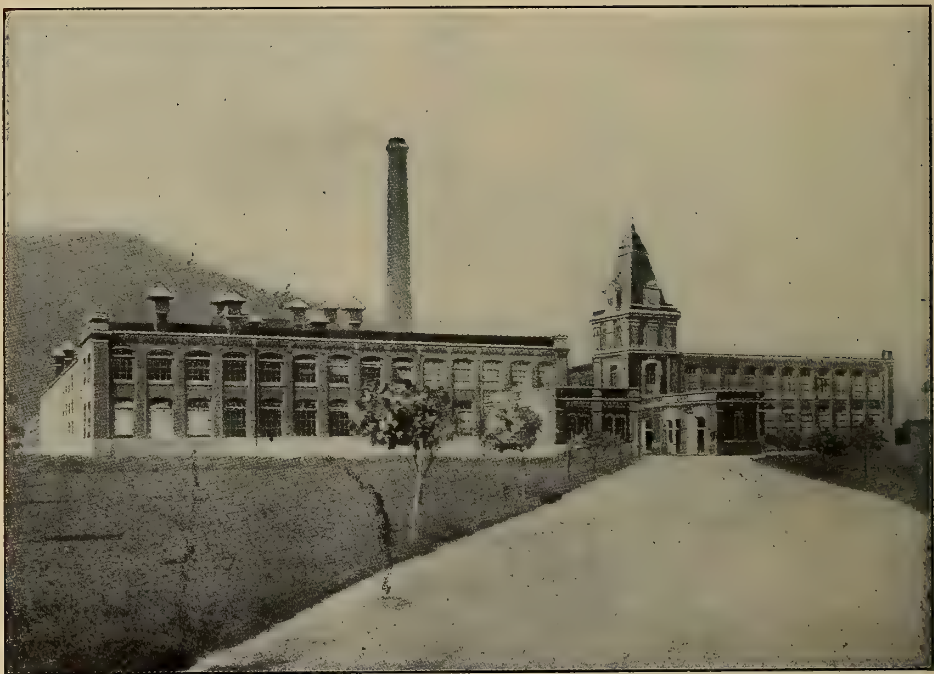


FIG. 5.—BANGU MILL, RIO DE JANEIRO, BRAZIL. PLATT BROS. CO., LTD., OLDHAM

Since the radius of the cylinder must vary, as the wires are ground shorter, it is necessary that the bends, or part on which the flats slide as they travel round the cylinder, should be flexible, so that by

suitable setting screws they may be sprung into the smaller radius. Other methods are employed for producing the necessary concentricity: that of Messrs Platt Bros. consists of a narrow crescent bend *C* held at five points, at which are setting screws for constraining the flexible bend to the desired radius, the screws being held in a stiff arch bar as seen.

When the carded fibre leaves the engine, the thin, fleecy web, when held up to light, should show an even distribution of fibres over its area, an entire openness of fibres, a freedom from curls, webs or neps, and an absence of broken bits of leaf or husk. These latter are very persistent and can rarely be absolutely eliminated. Some remain to be dragged loose in the drawing frames, and some even appear in the final yarn, only to be removed when the yarn is passed through a narrow slot in a steel plate in the subsequent operation of winding upon other bobbins. In fine spinning the additional process of combing clears the cotton of almost the last trace of specks.

COMBING.

This latest addition to processes is only common in fine spinning mills, though there is an increasing tendency to apply the process to coarser yarns. As the cotton comes from the cards its fibres are not parallel. They can be made parallel by sufficient drawing, but by means of the comb they can be at once laid parallel. Combing serves also to remove all fibres that are less than the desired length. If a bundle of loosened fibre, such as a long curl of hair, be held near to one end and a comb be pushed down upon the hair and drawn away from the part held, all the fibres which do not extend so far as the point held will be pushed in front of the comb and separated from the remaining longer fibres, which will be stretched out straight and parallel by the passage of the comb teeth. If now the hair be held near to the other end—now combed out straight—and the comb again inserted and drawn towards the previously held extremity, it will comb out all the hairs whose ends are not

FIG. 6.—A MODERN PAIR OF COTTON MILLS. MACHINERY BY PLATT BROS. & CO., LTD., OLDHAM

held in this second hold. Obviously, all the hair now left will be longer than the distance between the two held points. This is the operation which is carried out by the combing machine. It is, of necessity, a discontinuous process, for the sliver to be combed must be projected in short lengths of an inch or more, according to quality; these ends must be combed out by one comb while held by a nipper further back; another comb must descend on the first comb sets to work and removes this short fibre as well as combing straight the fresh projected ends. As each short length of sliver is combed out, it is laid overlapping the previously combed length and leaves this part of the machine as a continuous band again, and since each machine combs six slivers, there are six combed slivers finally laid together and combined into one sliver for the drawing operation which follows. To prepare the carded sliver

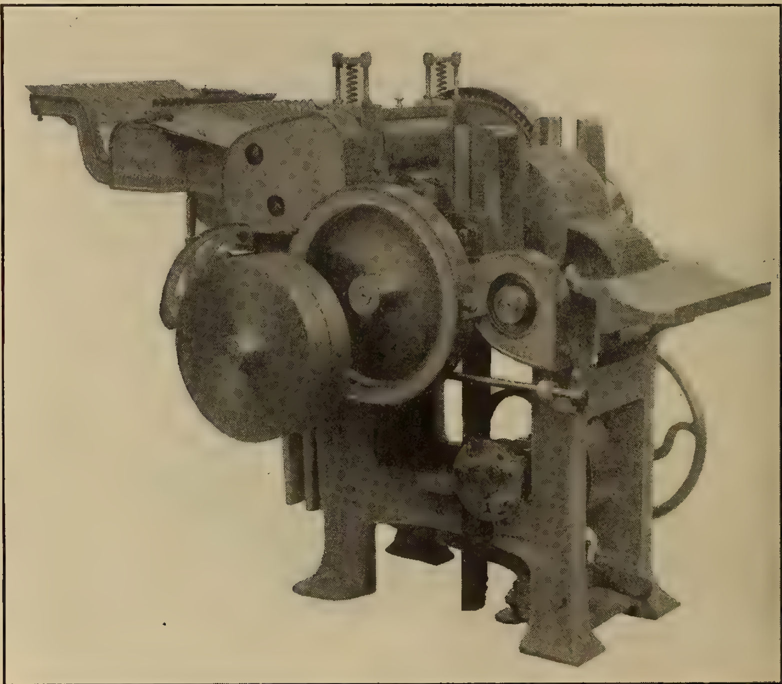


FIG. 7.—SLIVER LAP MACHINE. DOBSON & BARLOW, LTD.

sliver at the combed side of the nip; the already combed end of fibre must be seized by a fresh nipper, and, the back nip or hold being released, the fibres must now be drawn away from the comb, and the short combed-out fibres will now remain behind this second comb. This comb is now released, the sliver shot forward another length, carrying the crumpled short fibres upon it as left by the second comb, and the back nip being again established upon the fibre, the

for combing, some fourteen to twenty-four cans of card sliver are wound to form a cylinder from 7 to 12 inches in length. The united slivers are drawn out somewhat in passing through the three pairs of drawing rollers. The lap formed by this sliver-lap machine, Fig 7, is not quite even in thickness throughout its breadth, because the card slivers are not flat, but rather rounded in shape, and a sliver lap is a trifle corrugated if seen in cross-section.

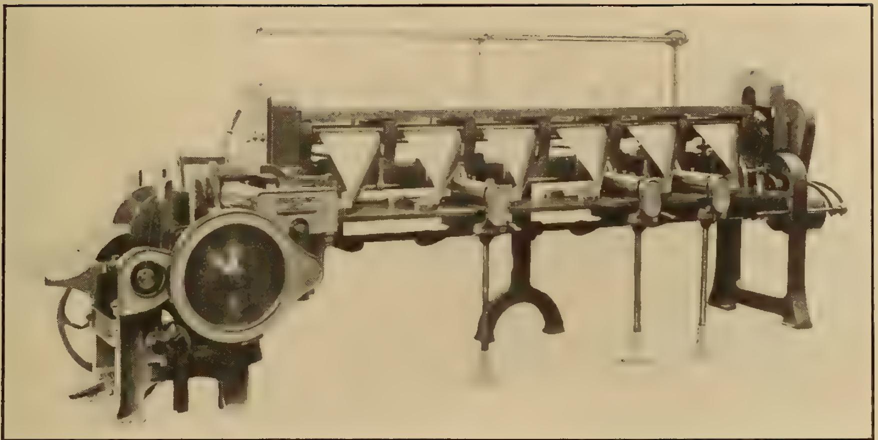


FIG. 8.—RIBBON LAP MACHINE. DOBSON & BARLOW, LTD.

Six of these sliver laps are now laid upon each other in a ribbon-lap machine, Fig. 8, each being drawn down between rollers, turned at right angles to the rollers and superposed, as shown, by peculiar turning plates, the whole being further drawn at the end of the machine and formed into a lap fit for the combs. All this drawing and duplication adds to the evenness of the flat sliver ribbon and enables the nips of the comb to hold all the fibres which come under the nip, this preventing excessive waste from slip, as well as helping to a preliminary straightening of the fibres, and so again saving long fibres which may be so much curled round as to be acted on as if short.

For this reason, some mills pass the card sliver through one head of drawing before preparing the lap for the combs, the sliver lap being made from slivers already passed through one drawhead and drawn six times in length.

To return to the combing machine, Fig. 9, this is usually made with six combs to comb six ribbon laps and deliver one combed sliver into one

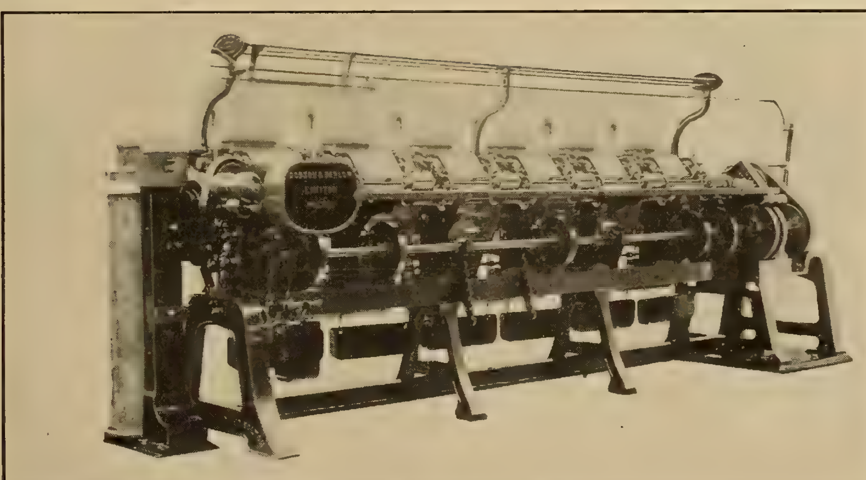


FIG. 9.—HEILMANN COMBING MACHINE. DOBSON & BARLOW, LTD., BOLTON

can. The ribbon lap is placed on rollers behind the machine, and the ribbon sliver is turned slowly off the rotating lap by the slow movement of these supporting rollers. It descends over a smooth plate and passes between two small feed rollers, which turn outwards intermittently to throw forward the length of fibre to be combed. Upon this fibre descends a nipper plate, which has a peculiarly curved edge, which nips the fibre upon the edge of a leather-covered plate below; the fibres to be combed hanging freely from the held point or nip below, while close up to the lower nip plate, in the combing roller covered with rows of comb teeth over part of its circumference. When the nip is made, the first row of teeth is ready to act. There will be as many as seventeen lines of short-comb teeth or needles, the first being coarser than the next, and so on, to the last finest set. These graduated teeth segments are all separately fixed. As the teeth pass through the out-hanging fibres these may be seen gradually to draw out straight and parallel, the noil or loose, short fibre left by the top comb, as well as the loose fibres in the projecting sliver, pass forward on the teeth of the cylindrical comb. A pair of small diameter rollers, which still hold the length of fibre previously combed, now commence to turn backwards and throw back the combed sliver ends over the ends of the freshly combed sliver, thus piecing up again the discontinuous web. These small detaching rollers now again turn forwards, drawing the new sliver ends between them, and the single top comb having descended upon the sliver in front of the nip, and the nip being released, the rollers now draw the sliver forward through the top comb, which pushes back the loose fibre, to be afterwards removed by the lower sets of combs as described. The waste on the lower comb is removed by a circular brush, picked off this by a wire-covered doffing roller, which, in turn, is stripped by a reciprocating comb. This waste is sold for the spinning of less fine counts.

FIG. 10.—DELTA MILL, ROYTON. MACHINERY BY PLATT BROS. & CO., LTD., OLDHAM

From the detaching rollers the combed sliver issues as a fleecy web, and the six webs made in each machine of six combs are combined into a single sliver, which is now ready for drawing. The Heilmann comb

is made by all makers, but Messrs. John Hetherington & Sons make a form with a double nip, two sets of combs on the under cylinder and two blank segments instead of one of each as in the single-nip machine. The detaching roller, which swings to and fro, as well as turning backwards, for piecing up the combined sliver, is worked at double speed by means of two cams and more output is obtained. The nipper plate, as well as the detaching roller, has a swinging movement to and from the detaching roller, and by this movement it throws the combed sliver upon the ends which project from the detaching rollers and form the piecing. The ends are taken hold of by the rollers, and the top roller swings back from the advancing nipper and the top comb descends through the sliver, and both it and the nipper now retreat and comb back the sliver now held in the nip of the rollers. It must also be observed that in the cylinder comb there is a recess between the last row of teeth and the plain portion, into which, when the detaching rollers turn backwards, the thrown back ends of sliver enter and are stroked down under the lower detaching roller by the advancing radial face of the plain portion. It is on this stroked-down fibre that the piecing up is made, and the pieced sliver is then drawn forward as the rollers again turn forward. The forward turning of the rollers is, of course, greater than the backward turning. In the Nasmith combing machine made by John Hetherington & Sons certain improvements are made upon the original Heilmann machine, such as a greater overlap of the piecing, a slower advance of the nipper towards the rollers, and an easier and more gentle closing of the nipper, and a better output is obtained from this machine.

Following upon the carding engine for coarse counts, or after the combs for fine counts, comes the operation of drawing. As stated previously, a drawing operation may also take

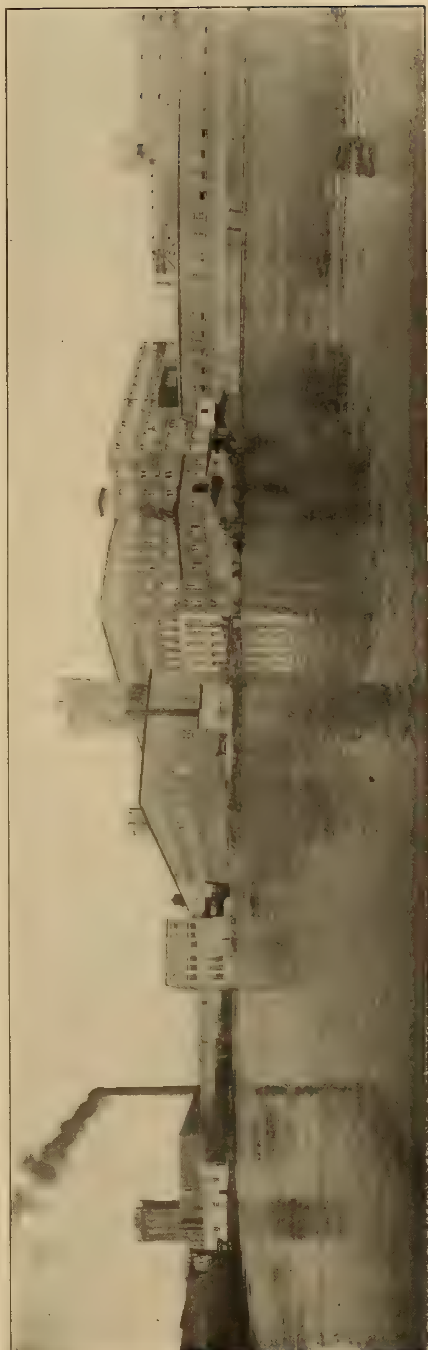


FIG. 11.—VALLEYFIELD MILLS, CANADA. MONTREAL COTTON CO., VALLEYFIELD

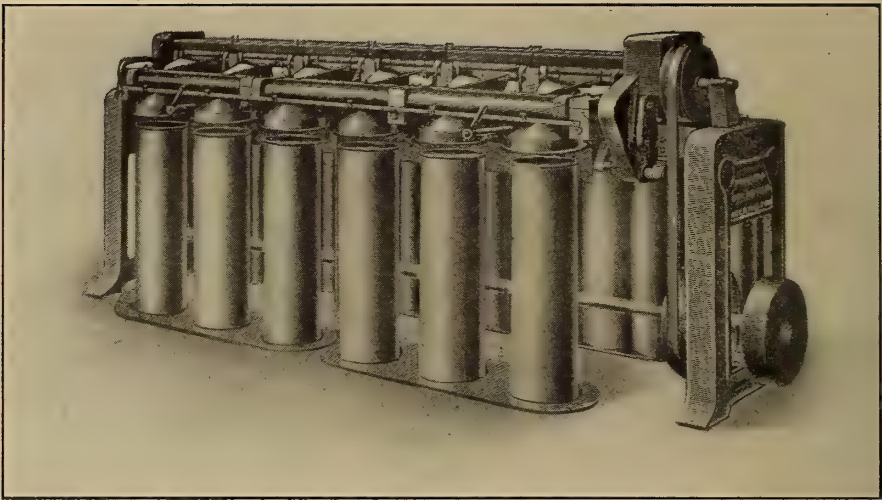


FIG. 12.—DRAWING FRAME. HOWARD & BULLOUGH, LTD., ACCRINGTON

place between the carding and the combing operations, in order somewhat to ease the duty of the combs and to prevent a little of the waste of long fibres, for the operation of combing will remove practically every fibre which is not held at one end, and even the longest fibres may be laid so transversely as not to be held by the nip. The draught in the sliver lap machine and in the ribbon-lap machine does much, however, towards laying fibres sufficiently parallel to be combed without undue waste.

DRAWING.

Drawing is one of the most important processes in the preparation of cotton for spinning. If a tuft of raw cotton from the bale or from one of the earlier opening or scutching processes be held between the thumb and fore finger of each hand and pulled slowly apart, preferably under a magnifying glass, it will be observed that many of the fibres are hooked or looped into others. Under the stress of the pull, the loosest end of a looped fibre is pulled from its hold on the other fibres and drawn out straight, and when the tuft has been pulled in two, the parted ends are seen to consist of approximately parallel projecting fibres. By laying the two tufts upon each other, with these fibres parallel and again pulling apart, and repeating this process several times, all the fibres will be found to have come unwound and to be lying straight and in one direction. The operation of drawing is a mechanical reproduction of this process. A drawing frame, Figs. 12 and 13, consists essentially of a frame carrying four rows of finely-fluted rollers with top rollers leather covered and weighted. About six or eight sliver cans to each section of roller are brought together and put through the rear of the four pairs of rollers. This roller rotates at a moderate speed; the second row of rollers runs 50 per cent. faster; the third row nearly 600 per cent., and the fourth 600 per cent. as fast as No. 1. The six or eight slivers are thus drawn down to one of about the same weight as each of the six or eight, and in this long draw, the curled and looped fibres have become much straightened out. The drawn sliver goes into a can just as it does when it leaves the carding engine, and six or eight of these cans are in turn passed through a second drawhead of four rollers, and usually a third, especially for finer counts. Thus, there may be

two draws of 8 × 8, or three of 8 × 6 × 6, or three of 8 × 8 × 8, representing 64, 288 or 512 reduplications of the card sliver.

In this way any fault in any one lap has been reduced to one of no importance, impossible to be measured. The averaging capacity of the drawing frames is at the root of the evenness of the yarn. Each sliver as it enters the frame passes over a short channel end lever, so that if any sliver breaks, the lever drops back and by a simple gear stops the frame, which also stops if the delivery sliver should break or possibly catch up and wind on the fourth roller or other roller.

Thus the carded cotton, which arrives coiled in cans at the first draw head, leaves the last draw head in similar cans for the next two or three processes, known as first slubbing, intermediate and roving. The operation of drawing serves two purposes. First it produces parallelism of the fibres, and secondly it eliminates irregularities in the sliver by the averaging effect produced by the hundreds of duplications whereby any thick or thin sliver is nullified in its effect. Obviously, therefore, where the reduplication of the combing process and sliver lap machines is omitted, as with coarse counts, the drawing process will be of even greater importance, and for fine counts the fibres cannot well be made straighter than they are left by the combs, so that so extensive a system of drawing after combing is not so necessary. Still it is necessary to draw after combing, since the sliver from the combs is built up as described by laying each short combed length of fibre upon ends of adjoining lengths; and the sliver cannot, therefore, be quite even along its length, and must be made so by the reduplication effect of drawing.

The important matter to watch in the drawing frame is that the dis-

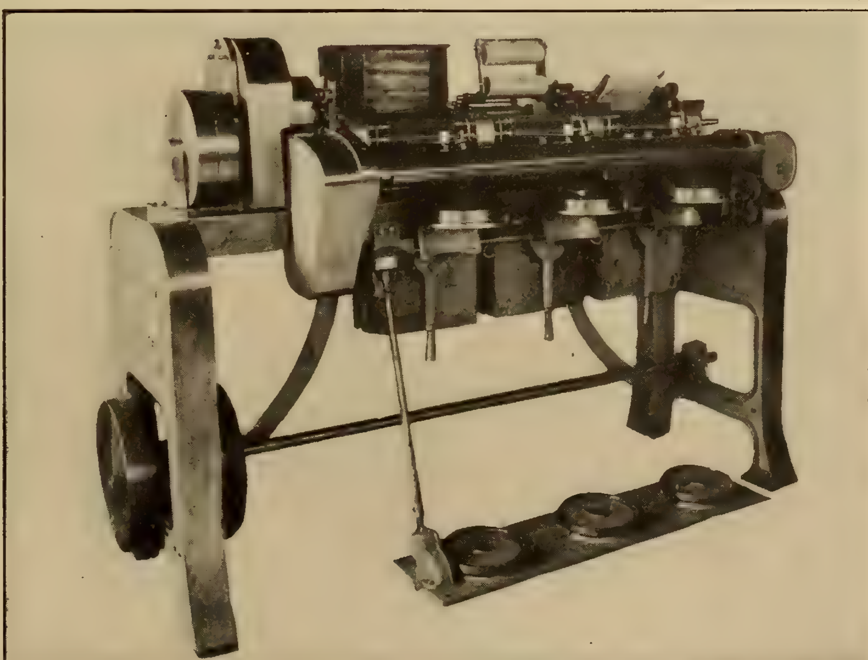


FIG. 13.—DRAWING FRAMES (THREE DELIVERIES), SHOWING ROLLER WEIGHTING, TOP CLEARERS RAISED AND DELIVERY CANS REMOVED. DOBSON & BARLOW, LTD.

tance apart of any pair of the four drawing rollers shall be greater than the longest fibres of the material. If this be not arranged there would be fibres held by two pairs of rollers at one time, and since any pair always rotates faster than the next behind it, the fibres would be broken in the draught, the leather covers of the top rollers would be destroyed by friction, and there would be an enormous addition to the power necessary to drive the mill. It would require several thousand pounds' pull to break the 70,000 threads that are at one time being spun in an ordinary mill. Each of these simple threads is represented by two places of pull in the spinning frames, by six equivalents in the intermediate machinery and by nine in the drawing, so that the actual pull is equal to the combined tension of a million and a quarter simple threads, or a possible 200,000 pounds. In brief, a mill with short-fibre machinery could not work long stuff, though the converse would be possible.

Since the drawing frame runs at a high speed, it is necessary promptly to stop it if a sliver breaks, and for this purpose the slivers run over a spoon lever at the entry side, and the breakage of a single sliver will stop the frame; for the lever, when released from the pull of the sliver, falls back slightly, and its lower hooked end is caught by an oscillating bar, and this causes movement to be communicated to the belt fork. Howard & Bullough apply electric stop motions at all points of the machine. Thus, if a sliver breaks the top roller naturally comes into contact with the lower roller, and this completes an electrical circuit and causes the machine to stop very promptly. Thus the electric stop will act if any sliver can runs empty or a sliver breaks; if the sliver laps round either the top or bottom front roller; if the sliver breaks at the delivery or front side of the machine, or when the delivery sliver can is full under the coiler. The electric stop motion depends on the fact that cotton fibre is a good insulator. The sliver delivered by a drawing frame is delivered into a can by a coiling plate above, exactly as in the can-filling motion of the carding engine or combing machine. The can has a slow rotation about its vertical axis, and the circle of the coiler is half that of the can, so that the sliver is coiled in a series of circles, each re-

FIG. 14.—MILL OF MR. BONIGNO CRESPI AT CRESPI SULL 'ADDA, MILAN. MACHINERY BY PLATT BROS. CO., LTD., OLDHAM

moved slightly from the adjoining coil. In order to relieve the pull on the sliver as a can becomes empty, it is now quite usual to fit a loose bottom to the cans with a very light spiral spring below it. This raises the bottom and the coiled sliver upon it when the can becomes partially empty, and thus reduces the long hanging weight of sliver. This serves to prevent sliver from pulling apart or even slightly drawing out. This is especially desirable with combed sliver, for there is very little grip of the untwisted fibres upon each other, such as is given being only that of the compressing rollers through which the sliver passes on its way to a can. Up to this point, unless it be the very slight twist that is put in by the slow revolution of the cans, there is no twist in the sliver. No spinning has yet been done, but this commences at the next operation of slubbing, for a slubbing frame is a spinning frame pure and simple.

FIG. 15.—THE ORB MILL, WATERHEAD, OLDHAM

SLUBBING AND ROVING

Between the last head of drawing and the actual spinning there are two, three or even four reductions of the sliver carried out on the slubbing frame, the intermediate frame, the roving frame, and, in fine spinning mills, in the jack frame. These frames are all practically identical except as regards size. All of the same length, the first will contain usually 90 to 100 spindles with bobbins of 10 to 12 inches in length, the second 136 to 140 spindles with 9 to 11-inch bobbins, and the third will contain 176 to 180 spindles with 5 to 8-inch bobbins, while the fine roving frame will have 208 to 220 spindles. The spindles are set in two rows, alternating, and carry a flyer or fork, which is fixed upon the point of the spindle and extends downward the length of the bobbin. The flyer ends in a tubular top, and into this the sliver enters from the rollers, passes down one of the hollow legs of the flyer and emerges at the lower end, whence it is passed through the eye of a presser finger, which lays the reduced sliver evenly on the bobbin and presses it down firmly by virtue of pressure generated by the centrifugal force of a back vertical bar forming

a part of the finger attachment. Since the rollers rotate at a uniform speed, the surface velocity of the bobbin must differ from that of the flyer by just this front roller speed. This is easily obtained by simple gearing, the spindle being driven by one shaft and the bobbin by another one. These shafts pass in front of one row of spindles and behind the other row and drive the spindles by skew bevel gears. The bobbins are carried by collars, which slide on the spindles and are similarly driven. But the bobbin-driving shaft is carried on the copping rail, which rises and falls through the height of the bobbin and the spindles pass through bearings carried by this rail. The rail rises or falls by the thickness of the roving (or slubbing) each rotation, and thus lays the roving closely on the bobbin. A full layer being laid on from end to end of the bobbin, the next layer finds the bobbin thicker by two diameters of the roving, and this renders it necessary that when the bobbin follows the flyer its speed shall be increased with each layer, and the reverse if the flyer follows the bobbin. A differential speed must, therefore, be placed in the course of the bobbin-driving gear, which becomes far from simple, after all. This differential gear consists of a pair of conoidal bell drums some 3 feet in length. One cone is driven at a fixed rate by the spindle train. The bobbin train is driven through a jack-in-the-box motion from this same cone shaft, but the frame of the jack in the box motion is driven by the second cone, which, in turn, is driven by a belt from the first cone. This belt has a shifting fork moved by a rack, and the rack is driven by a link train so as to move the cone belt at each reversal of the bobbin rail and to vary the bobbin speed for each layer of roving. The mechanism is so contrived that it also reverses the bobbin rail with a shorter traverse

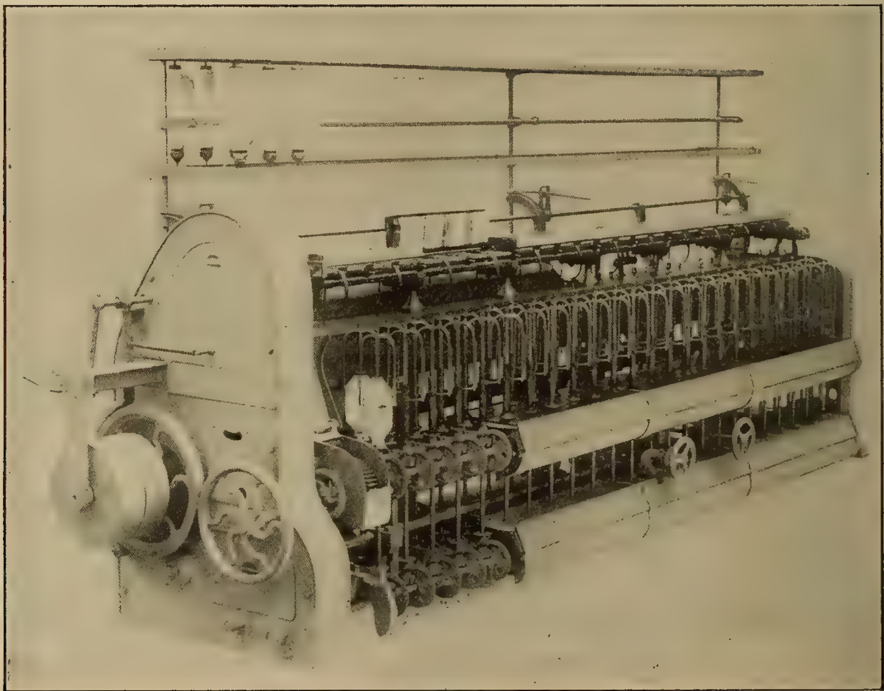


FIG. 16.—INTERMEDIATE SLUBBING FRAME. PLATT BROS. & CO., LTD., OLDHAM

every layer, the result being that a fitted bobbin consists of a parallel barrel of material coned down at each end to the bobbin, the angle per cone being about 45 degrees. Thus no ends are required on the bobbins, and the tubes are much less expensive than headed bobbins. The old-fashioned headed bobbins would chip round the edges of the heads and cause a lot of waste. In all these primary spinning frames the mechanism is identical, except in its size, to 4. There is, therefore, some slight cohesion of the fibres and some compression of the thread, but no very serious strength as yet, and there is a good deal of drawing yet to be done. In the first slubbing frame one can of sliver makes one thread of slubbing; but in the subsequent frames, Figs. 16-17, it is usual to effect a doubling of the thread from the previous frames.

The essentials of these machines are the usual three rows of rollers to

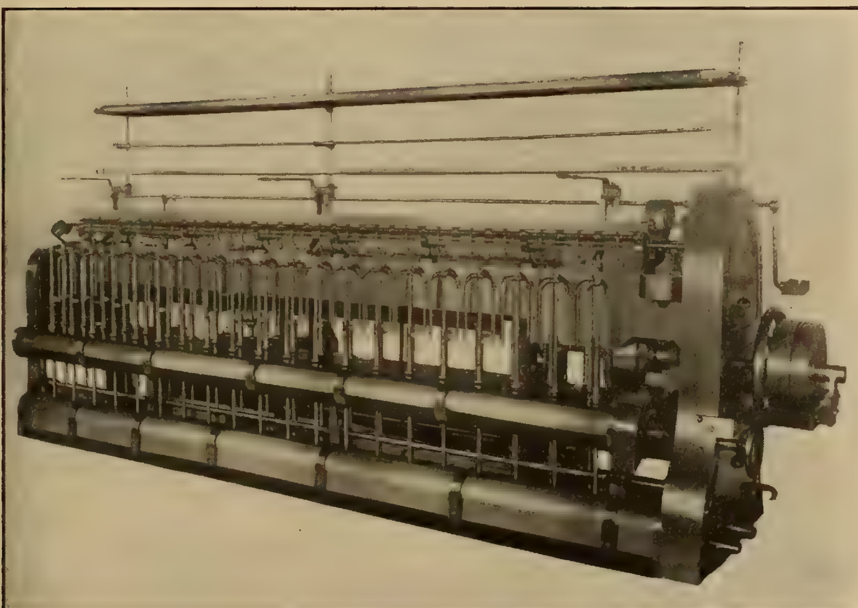


FIG. 17.—INTERMEDIATE SLUBBING FRAME (SHORT), BY DOBSON & BARLOW, LTD., BOLTON

and the object of these frames is gradually to reduce the material until it is about eight times the weight per hank of the final yarn. The spindles run at a speed of 440 to 600 for the largest size, 650 to 750 intermediate, 1,100 for roving, and 1,200 per minute for fine roving or jack frames; and the counts of the softly twisted yarn or roving vary from 0.5 to 1.3, 1.2 to 3.5, 3.0 to 7.0 and 7.0 to 16.0 or higher in the four frames, respectively, the number of turns or spinning thrown in per inch length being about 0.8, 1.4, 2 to 3 and 2½ deliver a fixed quantity of sliver; a spindle with a bobbin upon it, so driven by differential gear that the surface speed of the bobbin shall differ from that of the presser finger attached to the spindle by the amount of the front roller delivery; a variable-speed cone to effect this in conjunction with the differential gear, and a rising and falling rail to carry bobbins up and down their spindles at a decreasing traverse, so as to wind the yarn on the bobbin into cone shape. Before the invention of the differential motion the bobbins were

FIG. 18.—COPULL RING MILL, CHORLEY. MACHINERY BY PLATT BROS. & CO., LTD., OLDHAM

filled very loosely and held but little material; but the differential movement enabled bobbins to be hard wound and also allowed the roving to be made with a minimnm of twist, and thus the more easy of draught in the rollers.

Since the bobbin rail rises and falls, the bobbin driving shaft has to be driven through a radial swing frame from the fixed gearing; and, taken as a whole, these speed frames, as they have come to be called generically, are exceedingly ingenious adaptations of mechanism.

In coarse spinning these speed frames are the slubbing, the intermediate and the roving frame. In fine spinning a fine roving frame or jack frame is added to make a fourth in series of these preliminary reducing machines, Figs. 16-17.

They are practically identical in everything but size.

(To be Continued.)

THE MANUFACTURE OF HIGH-SPEED STEEL

By O. M. Becker

HARDENING. THE HIGH-HEAT TREATMENT PRACTICALLY APPLIED

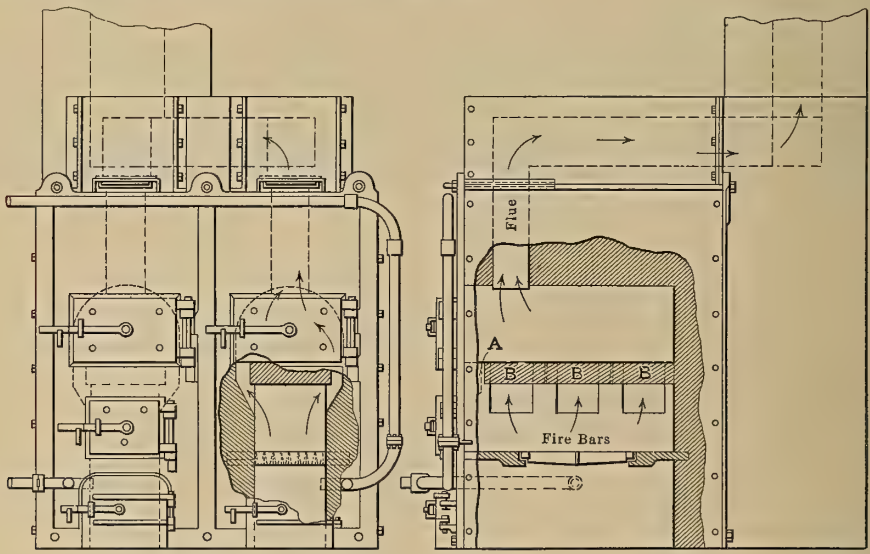
The present article is the third by Mr. Becker treating of the subject of the practical use of high-speed steel; the first, appearing in the August issue of this magazine, discussing the manufacture of the steel, and the second, in the December number, treated of the forging of the tools. The present article will be followed by another in the next issue, discussing the barium-chloride hardening process.—The Editor.

As in forging, so in hardening very crude apparatus can be utilized, sometimes with satisfactory results. For the hardening of an occasional tool only, it might be admissible to use the protected forge fire already described. But there would be no certainty in the results. A tool might, or might not, come out right. The only safe course is to use a properly designed furnace. If any considerable number of tools are used, a suitable equipment is indispensable if it is really desired to make tools which will exhibit the powers and advantages of high-speed steel to the fullest extent. The derision of over-refined methods, the feeling that tools "good enough" can be produced by common, crude methods, has no point. Over-refinement is, of course, possible, and the manufacture of tools can be made unnecessarily expensive. But it must not be forgotten that "good enough" in the case of high-speed steel tools means, if it means anything, that the tool is properly made and treated, so that it works at its best and does not become in the end a very expensive tool by failing or by spoiling a lot of work. For all work where endurance and accuracy count for anything—that is to say, where tools need to be accurately sized and to stay so for the maximum time, as well as to work during a maximum period—refined appliances and methods represent money profitably invested.

The coke or anthracite furnace described in the preceding article is well suited for hardening high-speed tools. When used for hardening heats, it is desirable that there be some arrangement for suspending the tools just above the fire bed, to keep them from contact with the fuel. A firebrick hearth or floor can be easily placed just above the fire bed, and this will be very convenient in doing some kinds of work.

The oil furnace is, in general, not suited to the hardening of high-speed tools. It is difficult to regulate the temperature or to keep it high enough; and ordinarily there is a good deal of oxidation. On finished tools this is particularly objectionable. The oxidizing action is in some cases partly obviated by the use of a muffle, and may indeed be wholly overcome by designing the furnace so that the tools are heated within a muffle or a crucible, which in turn is raised to a white heat by the rotating flames in the fire chamber. The flames must not be directed against the crucible, either in such an oil furnace or in a similarly designed gas furnace, else holes are likely to be melted into the pot. There is more or less difficulty even when a furnace of this type is carefully designed, in regulating the temperature and keeping it high enough. An English furnace, in which the flame is directed downward toward the floor of the fire chamber, is claimed to be quite satisfactory.

There is some diversity of opinion as to just which kind of fuel is best for high-speed steel heating, some maintaining that coke is not only ideal (which it certainly is), but the only fuel which allows absolute control of temperature. On the other hand, the experience of others shows that gas furnaces are now made which will accomplish practically all that any coke furnace will do. This type is unquestionably the most convenient; and while it is true that the first cost of gas seems high, when everything is considered, it really is will be so regulated that all the air will be consumed. The oxidation complained of not infrequently occurs because air currents enter the fire chamber through doors carelessly left open. Anyway, there is likely to be less of this scaling caused in the furnace than in the subsequent exposure to the air in cooling, or in carrying to the quenching bath. With proper care, all except those tools requiring the finest finish and the utmost precision can be hardened satisfactorily by using gas furnaces for the heating.



A COKE FURNACE USED IN HARDENING HIGH-SPEED TOOLS AT THE ROYAL SMALL-ARMS FACTORY, ENFIELD LOCK, ENGLAND

little, if any, more costly than any other satisfactory fuel.

The objection that in the gas furnace, as well as in others mentioned, oxidation of the tool takes place, has some foundation. It is true that, as often operated, the heating chamber of a gas furnace will contain more or less unconsumed air, and that some oxidation takes place as soon as the tools reach a high temperature, above a moderate red. Most of this, however, is unnecessary in a properly designed and intelligently operated furnace, for the supply of air and gas

This type of furnace can be used even where a supply of gas is not available, for fuel-gas manufacturing plants in size suitable for supplying an equipment of gas furnaces are obtainable at a cost and with an economy of production which makes them desirable even where artificial gas may be had at the customary price. The cost of gas is, generally speaking, in this way reduced at least a half. In any event, the cost of the fuel is by no means the most important item in the making of high-speed tools; nor indeed is it of great

consequence in computing the net results. A single expensive tool spoiled for want of suitable facilities for hardening it will pay for enough gas to heat a great many other tools. And with inadequate equipment many a tool is spoiled or imperfectly hardened, so that it falls below its maximum efficiency.

Producer gas, it should be stated, has not been found well adapted to the production of such high temperatures as those required in hardening high-speed tools. Oil or coal gas is recommended.

Excellent gas furnaces are easily obtainable at moderate cost, and it is not intended to consider here their proper design further than to point out a few important considerations. A furnace should be of such form that the heating chamber can be, if required, entirely enclosed, to prevent radiation and variations in temperature by entering air currents. The gas and air should be supplied to the fire chamber already mixed in proper proportion for complete combustion, and so directed that the heat falling upon the tools is, for the most part, that radiated from the firebrick walls of the chamber or oven. It is desirable, therefore, that the flame be given a reverberatory movement by suitably curved walls or muffle plates in the heating chamber, or a rotative motion by a tangential arrangement of the burners or nozzles, so that it will be directed past rather than toward the centre, where it would impinge directly upon the tool.

The air supply must be at a pressure of between one and two pounds per square inch, the air blast inducting the gas. Both air and gas supply must be under perfect control. These considerations hold in the case of forging and oil-tempering furnaces as well as with those used for hardening.

For special forms of tool, specially adapted furnaces are desirable. For long and slender tools, like taps, drills, reamers, and the like, which are best hardened suspended from the shank, a cylindrical or rectangular vertical furnace is much better than an oven furnace. A modification of this form is suitable also for hardening in an empty crucible, as is sometimes done. It resembles, in its general features, the oil crucible furnace illustrated. Other special forms also can be used to advantage where enough work is done to warrant their installation. Such is a special die-hardening furnace, which is designed to harden only the face of a large die. Oil-tempering and other furnaces for relieving hardness or strains also are essential to a well-equipped hardening plant. These will be described in another place.

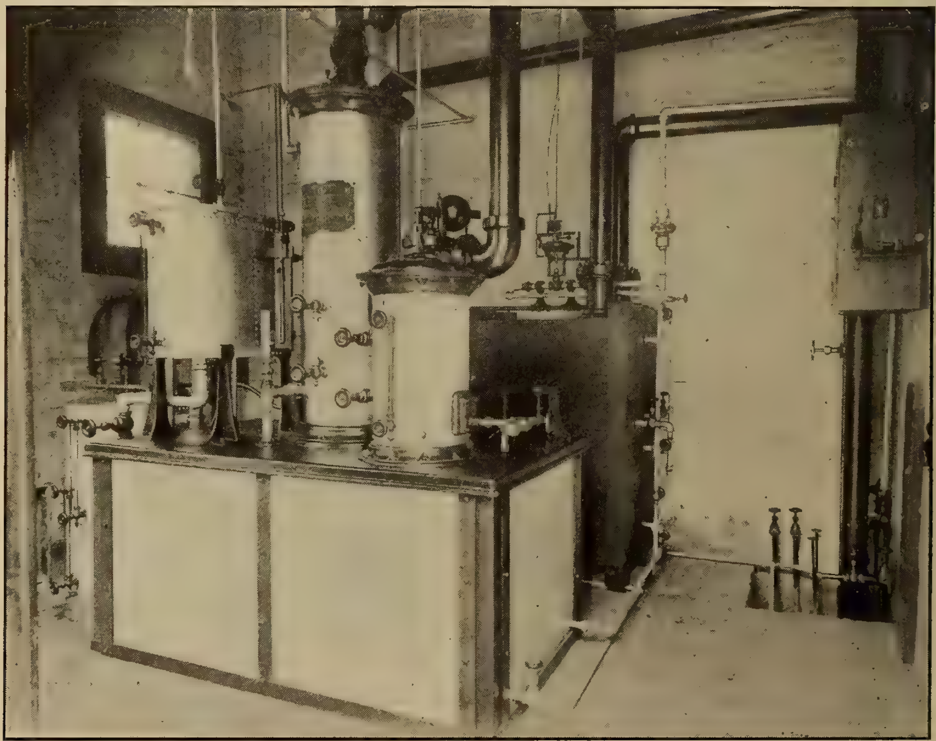
BRAYSHAW TWIN-CHAMBERED HARDENING FURNACE, FOR OIL OR GAS FUEL. THE ILLUSTRATION SHOWS THE FURNACE EQUIPPED FOR BURNING OIL. THE UPPER CHAMBER IS HEATED BY WASTE GASES FROM THE LOWER, AND IS USED FOR PREHEATING

The type of furnace to be used will, as may have been inferred, depend a good deal upon the kind of tool to be hardened, so that it is desirable to equip a hardening room with two or three different forms, to meet the varied requirements. There will also

be other appliances, such as those for quenching, for example. This seems a good place to enumerate what is essential or desirable, and to indicate the best arrangement for use.

The minimum equipment to be considered will include a combined forging and hardening furnace, of any of the kinds already described, and an oil quenching bath or a stream of air under slight pressure. The apparatus for air cooling may be of the crudest form—nothing more than a pipe of any desired size (not too small; say, not under ¾ inch) leading from the air supply and provided with a suitable cut-off or pressure-reducing valve, if compressed air is used. Occasionally tools can be hardened with no cooling apparatus whatever, merely being laid in a cool place, preferably where there is a current of moving air. This, however, is taking long chances on tools, for no certain results can be expected under such crude conditions.

A fairly complete outfit consists of a forge, an oven hardening furnace, an oil hardening bath or air-cooling table, and an oil tempering furnace. Both the latter are described in the paragraphs indicating their use. A well-equipped shop for forging and treating high-speed tools, however, would contain the following:



AN APPARATUS FOR PRODUCING GAS FROM NAPHTHA AT A LOW COST. DESIRABLE WHERE GAS IS NOT AVAILABLE, OR WHERE THE COST IS EXCESSIVELY HIGH. AMERICAN GAS FURNACE CO. INSTALLATION

A forge of suitable size for ordinary work. Its use has been already indicated.

A medium (or large, according to the work to be done) oven furnace for the hardening heats. The small oven furnace or forge would be used occasionally, no doubt, for small pieces. This furnace could be used also for what annealing would be

necessary in most hardening plants. It would, along with the forge, serve for pre-heating in connection with the barium process and the crucible furnace, as well as with the customary methods of hardening.

A cylindrical or rectangular vertical furnace of the kind already described for heating long, slender tools, which are best suspended from one end while being heated. If necessary, for the sake of economy, this furnace could be easily adapted so as to be suitable, when provided with a crucible for that purpose, for hardening in barium chloride, or for hardening in a crucible without a bath.

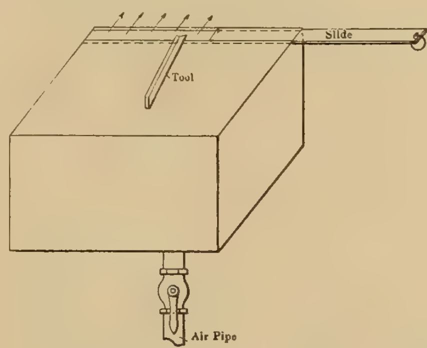
A lead bath is very useful where there is a wide range of work, but is not essential in high-speed tool hardening, especially if a barium furnace or a crucible furnace using no bath is adopted. A convenient and economical arrangement is a lead bath on the same base with a forge and oven furnace. This economizes space, and is very convenient.

A cylindrical crucible furnace, used without a bath. This is less convenient than an oven furnace, but is used in some plants because it practically prevents oxidation of fine tools while being heated. It does not, however, prevent oxidation to some extent when the tool is exposed to the air before or during quenching, and for that reason, among others, is less desirable than the barium bath furnace. The lead bath, barium bath and empty crucible furnace all can be so made as to utilize the cylindrical furnace body by interchangeable crucibles. The crevices can be luted up when making the changes with little trouble. It is, of course, more convenient to have a furnace of each kind which is likely to be much used in doing the kind of work in hand. In that case, this particular furnace will likely be omitted, unless it is the intention to heat tools by this method as a regular practice.

An oil-tempering furnace, for "drawing" the temper of such tools as require this to be done after hardening. This is described in a later article.

A quenching bath or air-cooling device. A very simple affair for cooling with air has been already referred to, which is quite good enough for rough tools of the simpler sort. For careful work a hardening table is desirable, and one suitable for this purpose is described in connection with the hardening process, as likewise is an oil-quenching bath.

A pyrometer, for gaging the temperature and checking against the operator's judgment, frequently is essential to continuous good results.



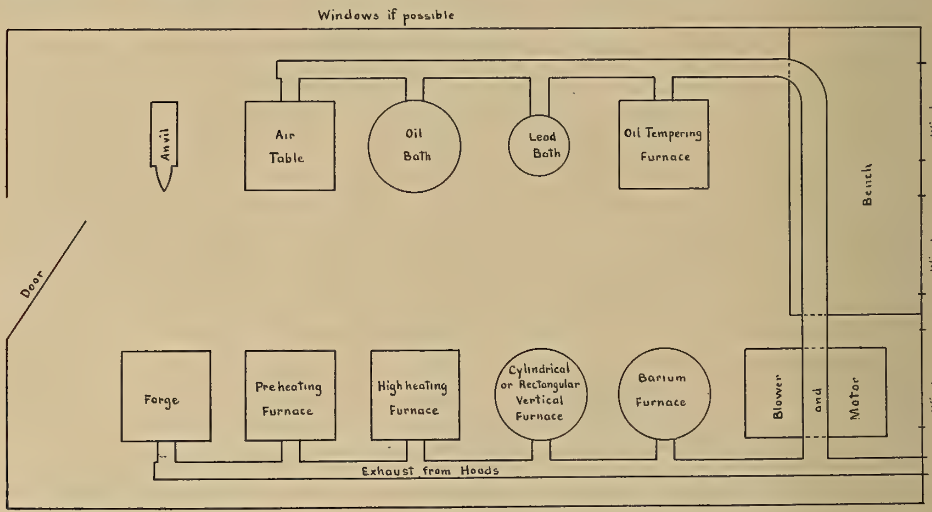
AIR BOX FOR AIR COOLING OF HIGH-SPEED TOOLS. CONVENIENT FOR HARDENING LATHE TOOLS AND THOSE OF SIMILAR SHAPE

The novice, especially in the manipulation of the new steels, needs the guidance of such an instrument; and the experienced operator himself cannot afford to get along without it, especially when working with the barium or other bath process. For the latter use a pyrometer of the thermopile or the resistance type is generally used; while either of these or a radiation pyrometer of the Fery type can be used with the direct-heating process. It is well to have the fire ends (where this type of pyrometer is used) interchangeable on the different furnaces, or with a separate set for each, any one of which may be switched into the circuit with the indicator or recorder, whichever may

be preferred. With but a single exception, so far as is known to the writer, no pyrometers are on the market which will give uninterrupted good service under the intense temperatures to which they are subjected in this kind of work. The fire ends break, having been used but a few times, enclosing porcelain tubes crack and crumble, or the thermo-couples deteriorate and cease to work properly. In any of these cases the indicator or recorder of course does not register correctly, and therefore is of small use, if indeed it does not mislead. When the fire end is suspected it is well to check it with another pyrometer of known accuracy, or with clay temperature-determining cones. These latter are very convenient also in the absence of a pyrometer, to determine high temperatures. They are cheap, accurate, and are obtainable in large variety. Each cone is numbered for identification, and melts down or fuses when the predetermined temperature has been reached which the particular cone was intended to indicate. The cones obviously are not available for determining the temperature of a molten substance, as in the case of the barium, lead or similar liquid baths.

If any forging is done in the hardening room, even though not regularly, there will be also an anvil and the tools usually accompanying the same. The anvil illustrated in the previous chapter, in connection with the forging of a Taylor standard tool, is very convenient.

There should be a suitable variety of tongs for handling tools, some of them of the conventional forms, and some in addition especially adapted to handling tools in such a way that the least possible surface of a tool heated all over will come into contact with the jaws. These latter may be in some cases have in-curved ends, or be studded with prongs, only the ends of the prongs in the latter case touching the tool being handled. Various desirable forms will readily suggest themselves as the occasion arises for their use.



LAYOUT OF HARDENING ROOM OF CAPACITY SUFFICIENT FOR HARDENING ALL THE TOOLS USED IN A LARGE MANUFACTURING PLANT

The arrangement of the various furnaces and baths will depend much upon the number to be installed, and the limitations of the hardening plant —among other things whether or not carbon steel tools, or even other objects, are to be hardened also. Assuming that a hardening plant for

high-speed tools only is contemplated, and is equipped with the appliances enumerated above, the arrangement would be somewhat like that shown herewith. At the extreme end would be the forge, and opposite it the anvil; next the small (if there be one) hardening furnace and the medium or large oven furnace, and beyond them the cylindrical and the barium furnace. Opposite these is the best place for the air table and oil bath, or either if but one is to be used. On the same side with the quenching appliances, and ranged at one side of them, are the lead bath, if there be one, and the oil tempering furnace. It is seen that this arrangement economizes space and practically centers the furnaces about the air table and quenching bath. The circular arrangement is avoided, though it is rather more convenient, because the space in which the operator works will doubtless be found quite hot enough without having focused upon him the radiation of all the furnaces which happen to be in use at one time. If coke furnaces are used, the arrangement would be different only to the extent that these replaced the gas furnaces here contemplated. There would perhaps be fewer of them, but each would occupy more space.

Each furnace and bath should be provided with a hood, preferably telescoping so as to permit lowering or raising as occasion may require, to carry away fumes, smoke and excess heat. It is desirable that the hoods be connected to a common vent which is exhausted by a fan. This will not only keep the room free from fumes, but will add greatly to the comfort of the operator by somewhat cooling the atmosphere by drawing new supplies of fresh air into the room. The fumes from the lead bath, at the high temperatures to which it is necessarily raised, and from the barium bath also under certain conditions, are very irritating and must not be allowed in the room.

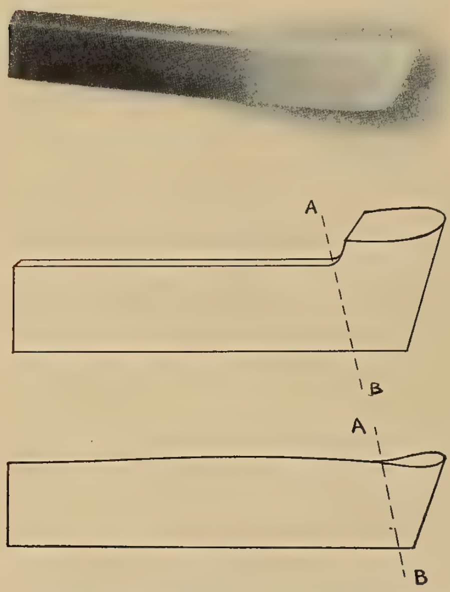
Heating high-speed tools for hardening is a very different thing from heating them for forging, not only with respect to the temperature, but to the variation in method also. The way in which a tool is heated and quenched, in hardening, depends very much upon its form and the use to which it is to be put.

Lathe, planer, slotting, boring, and the like tools can for the most part be readily ground to shape after hardening, and are on that account the simplest to treat. The heating which precedes the hardening proper may be done in any of the furnaces already designated as suitable for the purpose. It has been done successfully also in an ordinary smith's forge, though, as already pointed out, this method is not reliable and is undoubtedly responsible for many disappointments and failures. If no better means of heating is at hand, the forge fire should be covered with a hood, as already described in the chapter on forging, and the bricks well heated before placing any tools in the fire.

When using a fire of this kind, or a coke furnace alone, it is well to place a number of tools toward the edges of the fire or upon an ample foreplate provided for that purpose in the case of the coke furnace, bringing each in turn nearer to the hottest part of the fire. This allows of slowly bringing the temperature up to a bright red, about 1,000 degrees Centigrade. When this heat has been reached the tool may then be readily brought to a dazzling white, anywhere between 1,300 and 1,500 degrees Centigrade, at which point the surface begins to flux, and corners and edges show signs of melting down. A few steels will harden properly somewhat below this temperature, and it is well to note and follow the directions of the makers on this point. There need be no fear of overheating, for, as a rule, no good high-speed steel is injured by any heat to which it can be subjected in any fire such as has been here described.

The time required for bringing a

tool from the red to the white heat will, of course, vary with the size of the tool and the intensity of the heat; and under good conditions it should not need to take more than two minutes for a one-inch tool. It is important that the heat soak into the interior of the nose so that it is uniformly hot throughout; and that while the whole of the nose is so heated, the heat shall not soak up into the neck of the tool. The white heat should not pass beyond the line *AB,* shown in the illustration.



THE FIRST TOOL HAS BEEN HEATED RATHER FARTHER BACK THAN NECESSARY. THE LINES *A B* IN THE SECOND AND THIRD FIGURE INDICATE APPROXIMATELY THE EXTENT TO WHICH THE TOOL SHOULD BE THOROUGHLY HEATED

This refers, of course, to the annealed stock. If the unannealed stock is used, the heat should extend well back into the body of the tool, considerably beyond where it is to be quenched, so as to anneal this part as much as possible without a separate operation.

It is to be noted also that some makers of these steels recommend that the heating be gradual from the cold to the intensest white. This, however, does not seem to be really necessary, and it is usually more convenient to heat in the way indicated above, slowly to a red, and rapidly afterward to a dazzling white.

If the heating is done in a gas furnace, it is desirable that the first or slow heat be given in a pre-heating furnace, the tools being transferred to the high-heating furnace as fast as they can be handled conveniently. In using these furnaces greater care must be taken than with others usually, to avoid heating up into the tool.

All tools with projecting edges, gained surfaces, sharp angles or many clearances are peculiarly susceptible to cracking during and after hardening, unless this has been carefully and properly done. It is evident, therefore, that all possible precautions should be taken by the use not only of care and intelligence in the treatment, but of adequate and approved special appliances whenever these have been shown by experience to help bring the best results. The need for certain special hardening furnaces indicated in a previous paragraph is made very evident when tools of the classes just mentioned are to be hardened.

Such tools as long taps, reamers, drills, and the like, especially when slender, are very liable to warping and bending, unless heated (and cooled also) in a vertical position. They should therefore be suspended in the heating chamber by their shanks during the heating. A vertical furnace such as has been already described is desirable for this purpose, though a coke furnace could have its top suitably arranged to allow of the same thing. The shanks of the tools project through holes in the cover of the furnace and they are held in place by tongs or holders provided for that purpose. The pre-heating to a red color can be carried on in any convenient way. The temperature is not carried as high as in the case of tools which can be ground after hardening, and must always be short of the point where the cutting edges

begin to melt. The limit of temperature is about 1,250 degrees Centigrade (except for heavy roughing cutters, when it is 50 to 100 degrees higher), and may range downward to a hundred degrees below that point, or from a mellow white or light straw to a bright lemon or very light orange color. Where the tools are of such a kind that the cutting edge can conveniently be re-ground after hardening, the heat may be carried up to that generally given to forged tools, or perhaps a little above 1,300 degrees Centigrade. For most kinds of work tools are better for this, if they will allow of the higher heat. The tools must not be allowed to touch the fuel nor be exposed to a flame after reaching a yellow heat, lest the cutting edges be injured. It must be remembered that, as in the hardening of all high-speed tools (except as pointed out in the article dealing with the barium process), the heating must proceed evenly throughout the tool or throughout that part which is to be hardened. Otherwise strains are sure to be set up during the cooling which are not relieved by the ordinary methods of tempering even, and which inevitably affect the endurance of the tool. All tools of intricate shape are peculiarly susceptible to cracking from such strains, the defects frequently appearing long after the tools have been set at work, if not immediately after the cooling.

If a gas furnace is used to give the hardening heat, rather more care must be taken to keep the white heat in the nose of the tool. It is desirable also that the first or slow heat be given in a pre-heating furnace, the temperature of which is kept at or near a red heat, say about 700 or 800 degrees Centigrade. The tools are transferred to the high-heat furnace as rapidly as they can be handled conveniently. This serves the double purpose of preventing, in the case of large tools, the sudden lowering of the high temperature in the hardening furnace and the consequent need for regulating it again, and the blistering effect upon the surface of tools thrust cold into a furnace at white heat. Not only is the surface blistered under these circumstances, but the outside of the tool heats so rapidly that corners will be melted down and the tool will have the appearance of being ready for cooling when as a matter of fact the interior probably has not nearly reached the required temperature. A tool hardened in this way naturally would be defective.

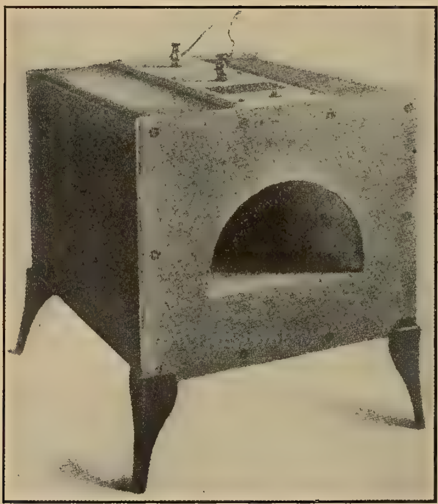
In order to avoid excessive grinding of the hardened tool, it should be brought pretty closely to the required shape on a dry emery wheel after it has cooled down from the forging heat and before being subjected to the hardening heat. Some allowance must of course be made for the grinding subsequent to the hardening, to remove the burned skin and restore the cutting edge.

Success in hardening these tools depends very largely in getting just the right temperature in the heating. It is very necessary therefore to watch carefully the progress of the heating when the color begins to verge on a light yellow, so that the cutting edges shall not be damaged and a crust formed which would afterward need grinding off and thus affect the size of the tool. It is well to consult the pyrometer frequently at this point, for the varying conditions of light on different days, and even in different parts of the same day, are quite enough to affect the judgment of the operator.

Milling cutters and similar formed tools are heated in practically the same way as are tools of the kind just considered, except that the cylindrical furnace is not used. It is no better than the oven furnace for these tools, if as good. The cutting teeth or edges must, however, be kept from contact with fuel or furnace walls and floors, and it is well therefore to set such tools on end upon a piece of fire brick of appropriate size, or to suspend them from above by a suitable arrangement. If such tools are of necessity heated in

a forge fire, they should be, like drills and reamers, frequently turned; and it is well to do this also, however they may be heated. The cutting edges must not be allowed, when at a yellow heat or above, to rub against the fuel; and it is better that they do not even come into contact with it. This is one of the reasons why a forge fire is not well suited to the hardening of fine tools. Another reason is the oxidation which inevitably takes place to a greater or less extent under such crude conditions.

The oxidation trouble is often very



AN ELECTRICALLY-HEATED FURNACE FOR HARDENING SMALL AND MEDIUM-SIZED PIECES

annoying, when it is not prevented, necessitating the re-grinding of tools after hardening, and consequently also necessitating making them in the first place enough larger than the finished size to provide for this contingency. Except in the forge fire, oxidation need not occur to any considerable extent in any properly designed and intelligently operated furnace. Ordinarily most of the oxidation takes place after removal from the furnace, and while the tool is exposed to the air. It is desirable, therefore, that tools be not carried exposed to the air any considerable distance for cooling. This is imperative in the case of all fine tools and those with sharp edges, unless they have been heated in a barium bath.

It is to prevent oxidation entirely that the lead bath, the empty crucible muffle furnace, and like means, have been resorted to. These will be further considered in connection with the barium process in a separate article. The "pack hardening" of fine tools serves its purpose effectively, but is now little practiced because the same results are now obtainable by less troublesome means.

Where adequate facilities for getting the same results in a quicker and more certain way are wanting, the method still serves a purpose. The usual practice is to enclose the cutters, if small, in a piece of wrought iron pipe, packed closely with charcoal, fine coke, or other customary packing, and the ends of the pipe sealed with clay. If much of this sort of work is to be done there should be a suitable pot, preferably of wrought iron. Cast iron will do, but it must be expected that the bottom will drop out occasionally, so intense is the heat required. Tools placed in the packing case should not touch each other, and where this can be done conveniently, should be suspended by a common support before packing, to facilitate their subsequent removal and quenching. The pot and contents after sealing up are placed in the white hot furnace until the whole is at the uniform high heat necessary for hardening the particular kind of tools in hand. No rule can be laid down for the length of time required, since that will depend entirely upon the size of the tools and pot. The operator must be guided by experience and the pyrometer. Some indications as to the condition of the tools may be obtained by the old expedient of withdrawing from time to time some wires previously inserted in the pot for that purpose. The contents having reached the necessary temperature, the pot is withdrawn, its contents removed and quenched as rapidly as possible.

It may be of interest to mention the causes of scaling or oxidation. The explanation is very simple. At high heats iron and oxygen (which latter constitutes about a fifth of the atmosphere) have a keen chemical affinity for each other, and the oxygen of the air attacks the hot iron (or steel) with great avidity. The resultant of their chemical combination is a scale constituted of iron oxide, which is the same as common red-iron rust except that the latter contains some water and the former does not. Scaling takes place also when steel or iron is left in contact with fuel through which air is passing or with which air is mixed. Hence the need for the cautions previously given with reference to such contact.

For hardening punches, punch dies, shear blades, forming dies, and a variety of other tools more or less like them in use, the heat is not brought as high, generally speaking, as for heating those classes of tools already considered. These tools preferably are ground closely to size before being hardened. The temperature is in all cases kept below a clear white—say at a lemon color or near 1,150 degrees Centigrade. From this it may range downward, according to the brand of steel used and the size of the tool, to a very bright red, about 950 degrees Centigrade. Small shear blades hardened at the higher temperature named give excellent service without being tempered. Chisels and other tools subjected to repeated shocks are taken at the lower temperature mentioned.

For convenience of reference the temperatures required for hardening the various kinds of high-speed tools are here summarized: Turning, planing, shaping, slotting, boring, and the like. Tools for roughing and medium cuts: a full to a dazzling white, between 1,400 to 1,500 degrees Centigrade. Milling cutters and similar tools for heavy roughing: a good white, approximately 1,300 or 1,350 degrees Centigrade.

Milling cutters for moderately light and finishing cuts, forming cutters, screw machine tools, tools for fine finishing and those which are to hold keen edges where the strain is not great, tools for cutting brass, and nearly all woodworking tools, a mellow white or light straw, or a little deeper, say from 1,250 to 1,200, or even 1,150 degrees Centigrade.

Twist and flat drills, reamers, threading dies and taps, and other tools subject to severe torsional strains: slightly lower than that given above, or say a little below 1,200 degrees Centigrade and down to about 1,175 or slightly below. This would give a light lemon color, verging into straw. It will not greatly matter if these tools be heated quite as high as those in the class above, though in general rather better results will follow if this difference be observed.

Shear blades, punches and punch dies, stamping and forming dies, pneumatic tools and others subjected to repeated jars or blows, 950 to 1,150, or from a bright cherry red to a light orange or lemon, according to the shape and use of the tool. Light punches and snap dies would be given the lower heats, as also would tools like file-cutting chisels.

It is well to remember in connection with the above summary that the hardening temperatures of high-speed steels vary more or less according to the composition, and that it is well to observe closely the instructions of the makers relative to this point, or better still to make careful determinations when any given steel is to be used, and thereafter to observe the limits found to be most satisfactory. In the nature of the case the above determinations are only general; but it is asserted with confidence that but little variation will be found desirable in the case of any high-speed steel of the now accepted standard composition—if it is not premature to speak of a standard composition.

For cooling high-speed tools either air or oil are used to good advantage. Cold water must on no account be allowed to come into contact with hot high-speed steel, for cracks will in-

stantly occur in that case. Hot water, speaking in a general way, does not cause cracks; and indeed has been used with some success for hardening, especially in the case of tools intended to work on exceedingly hard material. When so used it must be kept at a temperature of at least 70 degrees Centigrade. The novice would better let it alone.

In the early days of high-speed steel air was recommended by most makers to the exclusion of oil. It is coming to be pretty generally agreed now that if oil does not give better results, as some maintain, it at least does give quite as good as air, and that it has some advantages not possessed by the latter. Inasmuch as most high-speed steels harden by mere exposure to the air, little apparatus is absolutely required, as has been already noted. Some rather good results have been obtained in this simple way. The hardness of these steels, however, depends a good deal upon the rapidity and the method of cooling, on which account mere exposure to the air does not bring out the qualities of the tools to anything like their highest degree.

For many tools, therefore, this method is out of the question. To obtain uniformly good results the air should be in motion, and rather cool. Preferably it is supplied in a continuous and rather rapid stream, large in volume rather than high in pressure. Compressed air is better than that from a blower, since part of its latent heat has been extracted in the process of compression. The pressure must, however, be reduced to two or three pounds only at the nozzle.

For hardening an occasional tool, as has been already indicated, nothing further is required than a supply of air coming from a suitable nozzle of ample size. The tool is held in the blast and turned continuously until cold enough to handle, when it is laid aside in a dry place. Where many tools are to be hardened, even if only of the simplest kind, it is very desirable that there be a cooling table where the tools can be mechanically held and turned while the air blast plays upon them. Such an arrangement is also indispensable in the case of rotary cutters. A cooling table of simple design, used in the British Royal Small Arms Factory at Enfield Lock, is shown below. It consists essentially of an iron top table provided with a rotat-

TABLE FOR AIR HARDENING REVOLVING CUTTERS, AS USED AT THE ROYAL SMALL-ARMS FACTORY, ENFIELD LOCK, ENGLAND

ing plate and spindle between two movable nozzles from which the air blast issues. The spindle and plate can be provided with a clamp for holding laths and similar tools also. In cooling milling cutters and the like, the nozzles are turned to one side of the centre of the cutter so that the air will impinge upon the projecting teeth in such a way that they will act as valves and the cutter be therefore rapidly rotated by the air current. All cutting edges are in this way cooled with absolute uniformity.

It is well to make the spindle upon which milling cutters are mounted so it can be tilted and a part of the air blast forced through the hole, to carry away heat from the centre as well as from the edges.

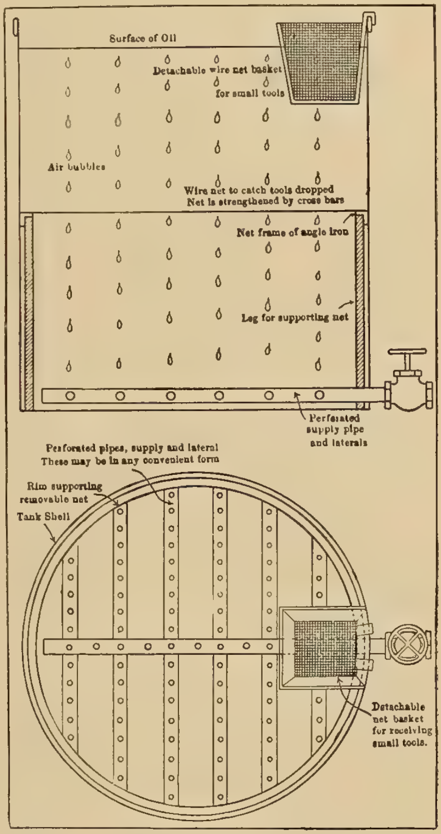
The convenience and simplicity of this method of hardening certainly recommends it. There are, however, certain disadvantages. The cost of air, for one thing, is considerable, and not comparable with that of maintaining an oil bath. The first cost of the latter is also the last cost,

except for the negligible item of renewal. In the air blast, furthermore, in spite of the rapidity of the cooling and the exercise of the greatest care, there will frequently be more or less oxidation; and this is not permissible in fine tools, at any rate, affecting their precision, as it does. Scaling is unimportant in the case of rough tools, since they are well, anyway, after hardening. Tools cooled in oil are, in general, harder than those cooled in air.

For hardening in oil the apparatus may be almost as simple as for air hardening. In small shops where but few tools are treated nothing more is required than a medium-sized tank full of oil. The shop doing a good deal of hardening, however, needs a bath of ample size equipped with some device for cooling and circulating the oil. Such a tank is shown opposite. It is seen to consist of a sheet-metal tank of suitable size, having a supply pipe and laterals at the bottom through which air under slight pressure is introduced. The pipes have small holes in their upper sides from which the air bubbles up through the oil, at the same time cooling and circulating it. A net for catching tools accidentally dropped is desirable, as also is a net basket at one side into which small tools may be thrown for quenching from time to time without further attention.

Various oils have been recommended for quenching high-speed steel, including linseed, cotton-seed, rope, fish, whale, lard, tallow, paraffine and even kerosene. It does not matter particularly, so far as the effect upon tools is concerned, which is used, so long as it is thin and does not become gummy. Some have certain disadvantages, though, which it is well to consider. Kerosene oil has in some hardening plants given better satisfaction than anything else. It does not flash, as might be expected, upon the hot tool coming in contact with the surface unless the quenching is very awkwardly done. If the tool is plunged quickly to a point below the heated portion, or entirely in the case of tools heated throughout, there will be no flashing.

Whale and fish oil are excellent agents, but have offensive odours. These can be easily suppressed, however, by the addition of about 3 per cent. of heavy (tempering) oil. This at first floats upon the surface, but usually mixes with the lighter oil



EXCELLENT DESIGN FOR OIL-HARDENING BATH. THE FIGURE IS SELF-EXPLANATORY

in time. The hardening is not affected by the added heavy oil, and this combination is about as satisfactory as could be.

Linseed oil is too gummy for general use. Lard oil becomes more or less rancid in time, but is excellent, and cotton-seed oil has practically no objectionable features. The point is not so much what kind of oil is used,

but that supply be ample to absorb the heat rapidly from the tool. Where much hardening is done it is, of course, necessary, as already noted, to provide a means for stirring and cooling the oil.

A little sal ammoniac added to the oil will make finished tools come out of the bath with clean surfaces. It does not, in small proportion, affect the efficacy of the quenching.

The quenching itself seems, and indeed is, a simple matter. There are, however, some points that should be carefully observed, to get uniformly good results.

First, the quenching must be done rapidly. Not only is the tool to be plunged into the oil with the least possible interval between this and the removal from the furnace, to avoid oxidation; but the plunging itself should be quickly done. Circular cutting tools, like milling cutters, are plunged with the axis vertical unless the thickness is considerably less than the diameter. In that case, they are quenched like thin dies; that is, in an upright position. Most other tools can be plunged with the long axis vertical. After immersion the tool can, of course, be turned to any position that may be convenient. The vertical plunging obviates to the largest possible extent the warping and cracking to which intricate tools are subject, and even those which are not intricate if carelessly quenched. A thin, flat die with relatively large surface, for example, if quenched so one face strikes the oil before the other, even if the intervening time be infinitesimal, almost invariably is warped so as to be useless.

In the case of drills, reamers, and the like, the heating has, of course, not extended the full length of the fluted part (unless, as rarely happens, the whole length of the flutes is intended to do work), and the quenching does not extend beyond the heated portion, say not beyond where it is red. This can be laid down as a safe general rule: a tool (except as indicated as above) should be quenched to a point somewhat nearer the cutting edge than that to which it has been heated, and worked up and down slightly while cooling. This will prevent a distinct line of demarkation between the hardened and the unhardened part, and avoids the trouble which sometimes occurs of a tool snapping off at that line. If of any considerable size, the tool must be kept moving in the bath, so that all parts immersed will be washed by cool oil, otherwise the oil in contact with the surface becomes so hot that hardening does not take place properly. This is especially true of tools of intricate shape or with many recesses, or containing small holes. In the last-named case the tool should be so moved in the bath that oil will flow freely into and through the openings. If several tools are quenched simultaneously, care should be taken that they do not touch one another, lest the places touching do not come into free contact with the oil, and consequently do not harden properly.

The method of hardening here described involves essentially this: The tool is heated to the highest temperature it will bear without injury to the cutting edge, and even to the melting point, if it can be afterwards well ground. It is then quickly cooled in an air blast or in an oil bath. This process is simpler than that patented by Taylor & White, is much more used, and is quite generally conceded to give results equally good with practically all standard (if it can be said that there is a standard) high-speed steel.

The Taylor-White process consists in the following steps:

First, the high-heat treatment. The tool is heated to the highest temperature it will bear, as in the general process already described. It is then cooled rapidly down to the "breaking-down" point, about 850 degrees Centigrade, and then cooled more or less slowly. Mr. Taylor says it is a matter of no particular importance whether the tool be cooled rapidly

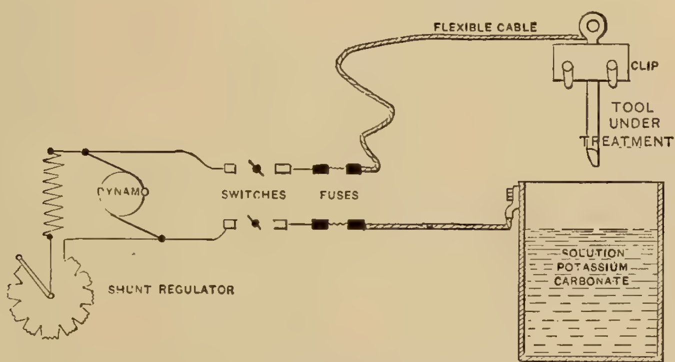
or slowly below this point, and indicates that it may just as well be cooled in the air blast as not, and does quite well if merely laid aside to cool in the normal atmosphere.

Second, the low-heat treatment. The tool is reheated to somewhere between 375 and 675, say to approximately 625 degrees Centigrade, preferably in a lead bath large enough to maintain a uniform temperature. The tool is kept at this temperature for about five minutes, and is then cooled, whether rapidly or slowly being a matter of indifference.

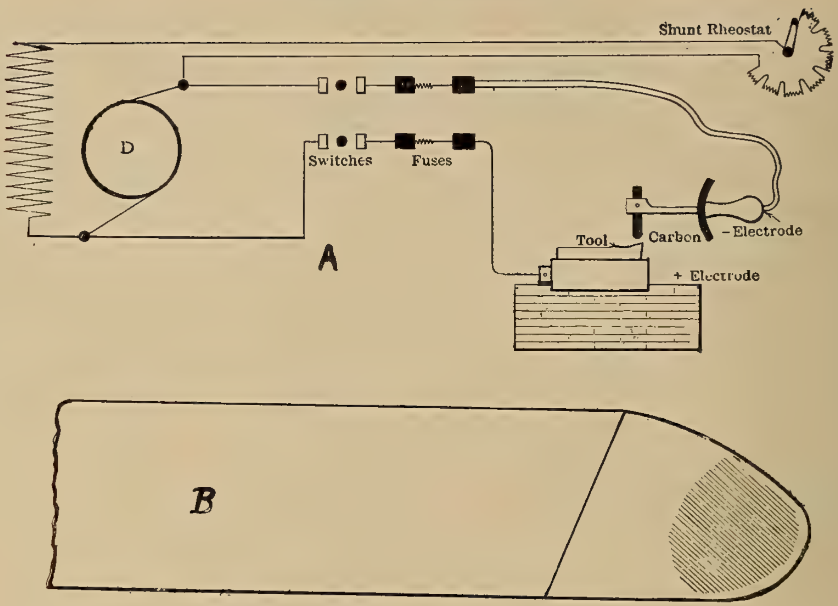
The only essential difference between the Taylor-White and the customary process is seen to be in the second or low-heat treatment, which is omitted in ordinary practice. In another place mention is made that high-speed tools do not run at their best until a short time after being set at work, after being "warmed up," so to speak. The warming up is not figurative, but real. The tool soon attains a temperature above the minimum range above given; that is, 376 degrees Centigrade, and therefore accomplishes while at work what is intended to be accomplished by the low-heat treatment. The self-treatment thus received by a tool does not normally give as high a temperature as that recommended by Mr. Taylor, unless run so rapidly that the cutting edge becomes red-hot—which is not good practice, generally speaking. The cooling naturally occurs when the tool is stopped preparatory to taking the next cut.

Apparently, therefore, the second or low-heat treatment is superfluous. It is maintained, nevertheless, that the self-treatment just referred to does not accomplish to the same extent what the low-heat treatment does, the temperature to which the tool is raised being rather too low under ordinary circumstances. However that may be, the second treatment is all but universally dispensed with.

A modification of the Taylor-White high-heat part of the treatment is sometimes recommended by the makers of particular brands of high-speed steel. The tool, after being brought to the requisite high heat, is transferred to a hot bath of some kind, whether lead, fusible salts, or the like, where it is cooled to a dull red, equivalent to a temperature near 675 degrees Centigrade—690 degrees Centigrade, according to one successful maker of many tools. It is then removed from the bath and allowed to cool naturally, or it may be rapidly cooled in an air blast or by quenching in oil. Mr. Gledhill recommends a still further modification, cooling to the point mentioned above, or slightly higher, in the air or in a blast, and then quenching in oil. As



ARRANGEMENT OF APPARATUS FOR HARDENING TOOLS ELECTRICALLY BY USE OF POTASSIUM CARBONATE BATH



ARRANGEMENT OF APPARATUS FOR HARDENING ELECTRICALLY BY USE OF THE ELECTRIC ARC. THE SHADED PORTION IN *B* INDICATES THE LOCATION OF THE CARBON POINT DURING THE HEATING. THE COOLING IS BY AIR BLAST OR OIL BATH, AS IN ORDINARY WAY

a matter of fact, it would seem that the manner of cooling is relatively of small consequence, except that if it be rather rapid in the first stage the result will be a somewhat better tool. But the high heat is absolutely essential; and the higher the heat, the better the tool—subject, of course, to the limitations already pointed out.

High-speed tools may be hardened electrically, though the process has not come into general use. No definite information is at hand as to the excellence of the tools so treated, though the results are said to be satisfactory. Two methods have been practiced to some extent.

In the first method the tool forms the positive electrode of a suitable electric circuit in which it is placed by being clamped in a suitable clip or holder. The other electrode is constituted of the walls of a cast-iron tank containing a strong solution of potassium carbonate. There are, of course, the necessary fuses, switches and current regulators. The current having been turned on, the tool is gently lowered into the solution to the depth to which it is to be hardened and moved up and down a little so as to avoid an abrupt transition from hardened to unhardened part. The tool on entering the bath completes the electric circuit, and an intense heat is set up in the part immersed. When this is seen to be sufficiently heated the current is switched off and the tool allowed to harden in the solution as though in an oil bath.

In the second method the electric arc is utilized. The tool is placed on an insulating block and attached to the positive electrode. The other electrode is a stick of carbon clamped in a safety holder. The current being on, at a low voltage, the carbon is touched to the part of the tool to be hardened and moved about as desired until the required heat has been attained, the voltage being gradually increased through a suitable rheostat. The tool is then cooled in the customary manner. This method evidently is suited only to local hardening, and not to the general run of tools.

THE DEVELOPMENT OF THE MECHANCAL ENGINEER

By George Frederic Stratton

IN an address recently made before a convention of labor delegates, the speaker enthusiastically inquired: "To whom can we credit the development of all the great mechanical arts if not to the workingman? Did any trained, professional engineer have anything to do with the practical adoption of steam for power, the invention of textile machines, or the adaptation of electricity for lighting and driving? George Stephenson was a fireman; Watt, an instrument maker; and Newcomen, a blacksmith. Arkwright, the inventor of the spinning machine, was a barber; Jacquard, of silk-loom fame, a typefounder. In our America, Fulton, the originator of the steamboat, was a painter; Corliss, a self-trained machinist; Robert Hoe, the greatest of printing-press inventors, was a tool maker. We find it the same with pioneers in electricity. Benjamin Franklin was a printer; Morse, a painter; Edison, a news seller and telegraph operator; Elihu Thomson, a chemist; Van Depoele, a cabinetmaker. It is true that Brush and Westinghouse were mechanical engineers, but they were not electrical engineers. That is the point I want to make—that these great industries were developed by men who were untrained in them. The engineer was a development of the industry, and the industry was initiated by the workingman."

This oration, although undoubtedly inspiring and correct in its premises, is incorrect in its deduction. It assumes that the notable inventors mentioned were men who simply invented their several creations without much preliminary study of the conditions and difficulties, and the means for overcoming them; whereas a review of the lives of these men will show, very plainly, that, before each great invention was perfected, the inventor had become trained, experienced and enlightened; his qualifications coming, it is true, not from college courses, but from daily and hourly study of the actual problems engaged upon; from the bitter experiences of repeated failures and from the clear, deep insight, which his protracted and persevering experiments gave him into every requisite element for ultimate success.

Looking at that group of men we find that George Stephenson worked fifteen years before achieving his decisive victory at Rainhill; Watt persevered thirty years while perfecting his condensing engine; Arkwright, hampered by poverty and scant knowledge of mechanical movements, laboriously constructed models of his spinning machine for six years before he could show sufficient promise in it to obtain the means for securing a patent. Jacquard fought difficulties and gained ten years' experience in inventing the figured fabric loom. Fulton studied steam engines for eight years before building his steamboat; Corliss was twelve years perfecting his valve system, and Hoe as long in developing the rotary press. Edison became an expert telegraph operator and intimately acquainted with all known phenomena of the electric current before he produced his first invention. Van Depoele, for his own amusement, conducted electric experiments in his Detroit cabi-

net shop for years before he became an inventor of car motors and the over-head trolley system.

This review shows that long and continuous periods of study, experimentation, and experience were required by each of those men in order to bring them to the focus of a practical realization of their initial, crude ideas. Each man was an engineer when he and his invention emerged, together, from the embryo condition of undevelopment. His diploma was not of parchment, but of iron and steel—the embodiment of the genius, knowledge, courage and determination found in men who may write Ph. D. after their names.

Of all those mentioned, the only men to secure quick success were Brush and Westinghouse, trained, mechanical engineers, and Thomson, the professor of chemistry. It was, undoubtedly, their college training, the knowledge of the value of methodical experimentation and systematic study, the ability to grasp a problem in the right way and solve it by logical and mathematical deduction which saved them from the heart-breaking failures and delays incident to the careers of untrained men.

This is why manufacturers and railroad managers—the great factors in industrial progress—look so eagerly for young engineers at the present time to fill executive positions which were fairly filled by overseers and foremen—men with capabilities for bossing, but of little or no scientific attainments.

The graduate of a scientific college or technical school is rarely adapted for such positions until he has taken a post-graduate course in actual contact with workmen and working conditions. In fact, in any position he is likely to be handicapped by one of two troubles—sometimes by both—underestimated by the workmen, or overestimated by his employers. By the one he is looked upon as an utterly unpracticed and impractical, grown-up school boy; by the other he is expected, by virtue of his diploma, to exercise qualities which can come only with experience; confidence amid unaccustomed surroundings, self-reliance under responsibility, and quick decision as to where his own knowledge and ability begin and end.

The great exploiters of industry understand and appreciate these difficulties, and frequently devise systems for the special purpose of affording the young engineer the opportunity to round out his college course with one which will broaden him into an experienced, self-reliant and efficient executive. The great railroad companies and manufacturing corporations, especially, are following up this line of development with, in almost all cases, evidently satisfactory results.

The system of one of the largest manufacturing companies of electrical machinery is, in its general principles, typical of many others in the mechanical industries, and a description of this system will serve to demonstrate the leading ideas of all.

It is known as the Student Course, and, nominally, continues four years, although no contract to that effect is made by the company or the student. Each is at liberty to close the connection at any time. Only graduates of colleges, technical schools, or approved correspondence schools are admitted. From the moment he starts upon the course the young man is under the same shop rules and discipline as the mechanic. He enters the plant at 7 o'clock A. M., dons overalls and goes at his particular job of assembling or testing. He works for three or four months in each great department and becomes familiar with every detail of the special apparatus made in that department—whether it be turbo generators, railway motors, arc lamps, transformers, dynamos, or any other of the numerous classes. He has nothing to do with machine-tool work or bench work. He assembles and tests; and thus acquires an intimate knowledge

of all types of machines and combinations of them, together with a comprehensive familiarity with the use of every description of testing and measuring instrument.

His general chief is the superintendent of assembling and testing, and as such work is usually carried on in the several departments where the principal parts are machined, isolated groups of these students will be found in every such department, working under the immediate supervision of one of their own number.

The student continues working in this way for at least two years, for fifty-five hours each week and fifty weeks each year. During the third year, changes in the programme will be noticed, apparently caused by the demands of the moment, but in reality contrived by the management, which is beginning to test the man. He will occasionally be sent away to examine and report upon some piece of apparatus which has got out of adjustment, or with a construction gang to help in installing and adjusting new machinery. He will be called into some one of the engineering departments to assist, for a week or two, in the clerical work—such as the making up of records or the correction of blue prints. He will find himself suddenly transferred from one job to another which, perhaps, may not be nearly so pleasant. But if he is shrewd and bright he will quickly understand that he is being treated as an emergency man and closely watched as such.

In his fourth year his ultimate destination, with that company, becomes clearly evident; a destination, however, for which his particular ability as well as his particular desire or ambition is consulted. He may elect to take up some special line of work—such as power machinery, or traction motors, or lighting apparatus—or he may prefer and be well adapted for the commercial department, the seeking of trade, the advising upon and designing of entire plants, and the making of the necessary contracts. In whatever line he takes up, his time will now be entirely occupied. He may continue out in the shops for another year, perfecting his knowledge of the smallest details of the particular apparatus upon which he is specializing, or, in the case of commercial work, he will at once go under the chief of that department.

Upon the termination of the course he is an assistant engineer and goes to any point of the company's several plants, or to any one of its distant offices where his services may be required. This system makes good men. The practical training, the acquired familiarity with the actual conditions of working apparatus as supplementary to the preliminary theoretical training, is invaluable. The student who is thoughtful, attentive and ambitious acquires, by this method, the qualities which must be combined to make the thorough engineer—nerve and resourcefulness with machinery in times of emergency, presence of mind, tact with and ability to manage men, business knowledge and executive capacity—all of which practice alone can give.

There are deep-seated purposes beneath this well-devised plan of training which are seldom apparent, at first, to the college graduate, and for that reason many of these do not take kindly to the idea of rugged, practical participation in the actual work of erecting and assembling—and the close juxtaposition with mechanics and helpers. It may be safely asserted, however, that not a man who has been through such training would, if he could, exchange it for four years at a desk in a consulting room.

The words of two great English scientists seem to express eloquently the underlying influences of these shop-training systems. In a recent address delivered by Sir Alexander B. W. Kennedy, president of the Institution of Civil Engineers, he said:

"Engineering problems differ from ordinary academically 'scientific' problems partly in that they are much

more complex and consequently more difficult of anything like exact solution, and still more because—exact or inexact—some solution of them has always got to be found; but it has to be translated into steel and gun metal as well as into pounds, shillings and pence, and any mistake will entail very much more serious consequences than a controversial paper in the *Philosophical Magazine*, or a letter in *Nature* pointing out a wrong estimate of terrestrial radio-activity in pre-historic epochs."

Those are hard, sound ideas, and in no manner can hard, sound ideas be so surely rubbed into a man as in a great manufacturing plant, bucking against sharp competition where quality and economy of construction *must* go hand in hand; where novelty of design and efficiency of output are understood as synonymous phrases.

Upon another point which, until late years, had rarely been considered in connection with engineering training, Professor Huxley said, in an address at the opening of the Technological College of Leeds:

"I confess I should like to see one addition made to the excellent scheme of education proposed for this college, in the shape of provision for teaching sociology. . . . It is not beside the mark to remind you that the prosperity of industry depends, not merely upon the improvement of manufacturing processes, not merely upon the ennobling of the individual character, but upon a clear understanding of the conditions of social life and of the men who work."

No one understands the vast importance of that thought more clearly and more willingly than the managers of operations involving great numbers of men of all classes. The engineer who supplements his scientific ability with a knowledge of workmen, of their feelings, their prejudices, their ambitions and their peculiarities either as individuals or as a class, is the man who gets results in work. And in no manner can this knowledge so quickly and so completely be obtained as in the daily and hourly contact with such men, working in comradeship with them, hearing their freely expressed opinions, and seeing from their point of view.

Those words of Professor Huxley were spoken nearly thirty years ago and are but recently bearing fruit. Any man who is old enough to have been a close observer of labor management a quarter century back, and who compares it with that of to-day, must be impressed with the great difference in the attitude of overseers and foremen of the two periods. While discipline has become more even, just, systematic and determinate, its administration has become smooth, dignified and even courteous. The old idea that bluster and sarcasm were necessary qualifications for an overseer is smashed. The gang foreman who deems it necessary to hurl invectives at the eyes and liver of his laborers is fast disappearing; the managers and superintendents will not tolerate him. And, although the old workman, looking back on the past, attributes the change to the influence of his union, it is the influence of the college which has produced it. It can be traced directly to, and coincidentally with the introduction of the educated, technical man into the great factories as an executive or assistant. His associations, his training and his ideals are altogether antagonistic to the bullying discourtesy, sometimes jocular but more often savage, with which the old-time overseer handled his men.

The influence of the new captain of industry is being continually exerted towards a more watchful care of equipment, a more humane treatment of animals, and a greater consideration for workingmen; and he is training his assistants to an understanding of, and attitude towards, the workman which, in addition to its humanitarianism, has been discovered as having a valuable bearing upon production.

LIVE LOADS AND WORKING STRESSES IN RAILWAY BRIDGES

By Conrad Gribble, A. M. I. C. E.

IN recent numbers of this magazine the author has given a short account of progress made during the last eighty years in the design of railway bridges in England, and as exemplified by the design of the main girders and the floor systems of typical bridges on the North-Eastern Railway, and on the many early lines of which it is composed.

The present article deals shortly with the subject of loading and working stresses in these bridges at the present day, comparing the conditions affecting the design of girder work in existence now with those of half a century ago.

The bulk of small bridges which are built of masonry or brickwork are not affected by increase of loading, since the margin of safety is so great, and, as a matter of fact, the live load hardly comes into consideration at all in the design of most masonry arches, as they are built according to general rules and not calculated for a definite stress per square inch on the material.

It is not very easy to ascertain what moving loads were assumed and allowed for in early bridges. The above table gives an approximate idea of the loads, which a number of girders built at different times will support safely, and is a rough guide to the weights of the engines in use when these bridges were built. In some cases there are notes on the original drawings giving this information; where this is not given, the safe loads have been calculated from the net flange area at the centre, and the dead load has been deducted to leave the available strength for live load only.

TABLE OF SAFE LIVE LOAD PER "TRACK" PER FOOT RUN AT DIFFERENT DATES.

Date.	Bridge.	Description.	Safe Live Load per "Track" per Foot Run
1830	Thornaby, R. Tees	Suspension	Designed for ¾ ton per foot run.
1850	R. Aire, Brotherton	Tubular	Designed for 1 ton per foot run.
1852	R. Swale, Maunby	Box	Designed for .67 ton per foot run.
1856	Staindrop Road, Darlington	Plate	Designed for 1.5 ton per foot run.
1861–62	Several bridges of about 60-foot span		Designed from 0.8 to 0.9 ton per foot run.
1860–70	Several bridges		1.5 ton per foot run.
1908	Present-day loading, covering modern locomotives and vehicles (including impact allowance)		50-foot span 3 tons. 100-foot span 2.2 tons. 200-foot span 2 tons.

Though during the last few years there has been a gradual but steady increase in the axle loads of locomotives and rolling stock, this progress cannot be maintained indefinitely, for more than one reason. The loading gauge of British railways is not large enough to allow the use of such huge locomotives as are common across the Atlantic, and the Engineer cannot permit any engines to be put on the line which will unduly stress the bridges. A great proportion of the bridge building in this country at present consists of the renewal of old wrought-iron and cast-iron structures, which have either become over-stressed by the great increase of rolling loads, or else have so deteriorated by corrosion as to be no longer safe for heavy

traffic. Both these causes are, as a rule, in existence.

It is not, of course, possible immediately to bring up to a new standard of strength the whole of the bridges on a great railway, but as each bridge renewal is dealt with, the strength is brought up to the full standard and, meanwhile, the loads allowed on any particular branch must be restricted to those considered safe for the various bridges situated upon it. If this work is systematically carried out, in a few years the carrying capacity of the line will be greatly increased by the employment of very heavy locomotives and high-capacity wagons. It is most important, however, that the strengthening and renewal of bridges should be carried out simultaneously with the gradual increase of loads.

Last year an enormously heavy engine has been put into service on the Great Western Railway. Though the "Great Bear" class has no axle weight of more than 20 tons (on the weigh-bridge), it has no fewer than three such loaded axles, besides a leading four-wheeled bogie, which carries 20 tons and a trailing axle carrying 16 tons. For a great many years other railways have been accustomed to locomotives with 20 tons per axle (and the North Eastern Railway has a class of mineral wagon giving 21 tons per axle), but it is a new departure to have such a succession of these heavy axles in one locomotive, and though cross-girders will not be more severely loaded than formerly, main girders of certain spans will have to bear increased weight. There are a large number of vehicles, such as boiler trolleys and steam cranes which, when fully loaded for transit, give greater loads on certain spans than locomotives. The conditions are, however, not quite the same, and it is probable that they do not stress the bridges over which they run to the same extent as locomotives, since they are propelled at only moderate speeds, and there are no such disturbing forces as those found in an engine due to the thrust of the connecting rod upon the rail, and to the oscillation and pitching occasionally induced at high speeds. Probably the axle loads of a locomotive are different when running at 60 miles an hour from those recorded when standing on the weigh bridge. It would at least be remarkable if it were not so, and when we have an engine with four highly weighted axles, it is probable that occasionally the concentrated loads inflicted upon cross-girders of bridges are very much more than would be allowed for by assuming the theoretical or "weigh-bridge" weights for these axles.

A comprehensive loading table for underbridges suitable for use in the engineer's office of a British railway must be a rather elaborate compilation, as it should give the equivalent load per foot run on girders of different spans, the concentrated loads on cross-girders of various spacings, also the maximum shearing forces in main girders of all spans at their ends and centers. The loads given in such tables will include a percentage of increase for impact, due to the motion and vibration of the loads, and also a small allowance for future increase; and, in compiling them, every vehicle must be considered, whether it is a locomotive, carriage, boiler wagon or steam crane, grouped in all probable combinations. The Board of Trade has for a long time fixed the limit of stress to be imposed upon the materials used in bridge manufacture; but their regulations are absolutely of no use for standardizing bridge calculations, as they are very general and incomplete. It may be well to look rather closely into them.

In the case of new lines the railway company furnishes the Board with all the information necessary for the calculation of the stresses in the bridges, and these stresses must not exceed those fixed by the Board in their regulations. The inspector examines the bridge and measures its deflection under the locomotives pro-

vided by the company, and if the result is satisfactory to him, he sanctions the opening of the railway, as far as the bridge is concerned.

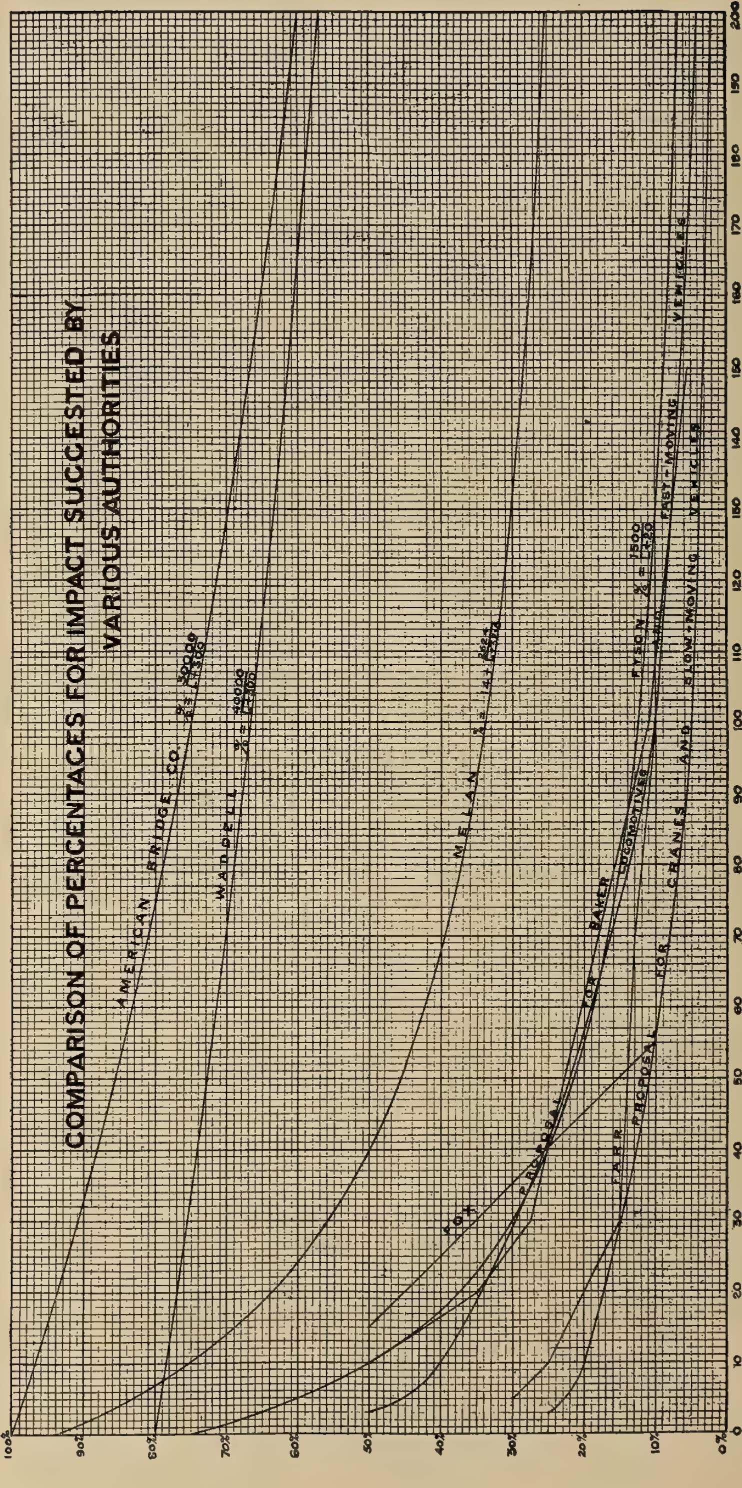
These prescribed working stresses already referred to are not given in great detail. They refer to three materials—cast iron, wrought iron, and steel.

Cast iron as a material for railway bridges is banned altogether, except where it is wholly in compression and when it forms part of an "overbridge." In these cases the Board requires a "factor of safety" of 3, and an allowance for "impact" on the live load of 100 per cent. The exact words are: "The breaking weight of the girders is not to be less than three times the permanent load, due to the superstructure, added to six times the greatest moving load that can be brought upon it." As far as "underbridges" are concerned, cast iron has nearly disappeared, but there are a large number of "overbridges" still in existence built of cast iron, and the strength of these is becoming an important consideration now-a-days, owing to the rapid increase in the weight and number of motor vehicles. It should be noted that though the breaking weight of the girder is to be the basis of the calculation for its strength, no information is vouchsafed as to the ultimate strength of cast iron, and unfortunately there is great difficulty in obtaining accurate data to assist in ascertaining this figure. Most of the experiments which have been made on cast iron have been on small pieces or model girders, and though in the case of other materials, such as wrought iron or steel, the strength of large girders could, with a great degree of accuracy, be deduced from such data, with the material under consideration this is not the case, and the results of small experiments, however carefully conducted, seem to give too high a figure to be applied to practical use. A large number of experiments have been made on small sections of cast iron which give a high average tensile strength in cross-breaking, and specifications for test bars of the material of an inch wide and 1 to 3 inches in depth require as much as 20 tons per square inch on the extreme fibres. As a matter of fact, ordinary cast-iron girders will not stand more than eight or nine tons per square inch. Hodgkinson's rule has been the basis of most of the calculations for cast-iron girders in this country, and though it is not a universally accurate formula, it is a useful guide. It is only really applicable to girders whose respective flanges bear a certain proportion in area to each other, and not to girders with equal flanges or with no top flange at all. Castings are so unreliable that a very accurate formula is of very little advantage, since a large factor of safety must be used. It is also unnecessary to estimate very closely the loads coming upon them, except in the case of old girders which are known to be over-stressed.

Trussed cast-iron girders require special calculation, but there are not many of these in existence now. Owing to an accident soon after their introduction they were discredited, and the majority were strengthened by timber struts below, carrying a great part of the load to the abutments.

Turning now to wrought iron and steel, we find that the Board of Trade requires a working stress of 5 tons per square inch for the former, and 6.5 tons for the latter. These stresses must not be exceeded by combining the dead load stress with that caused by the heaviest engines, boiler trucks or traveling cranes used on the railway.

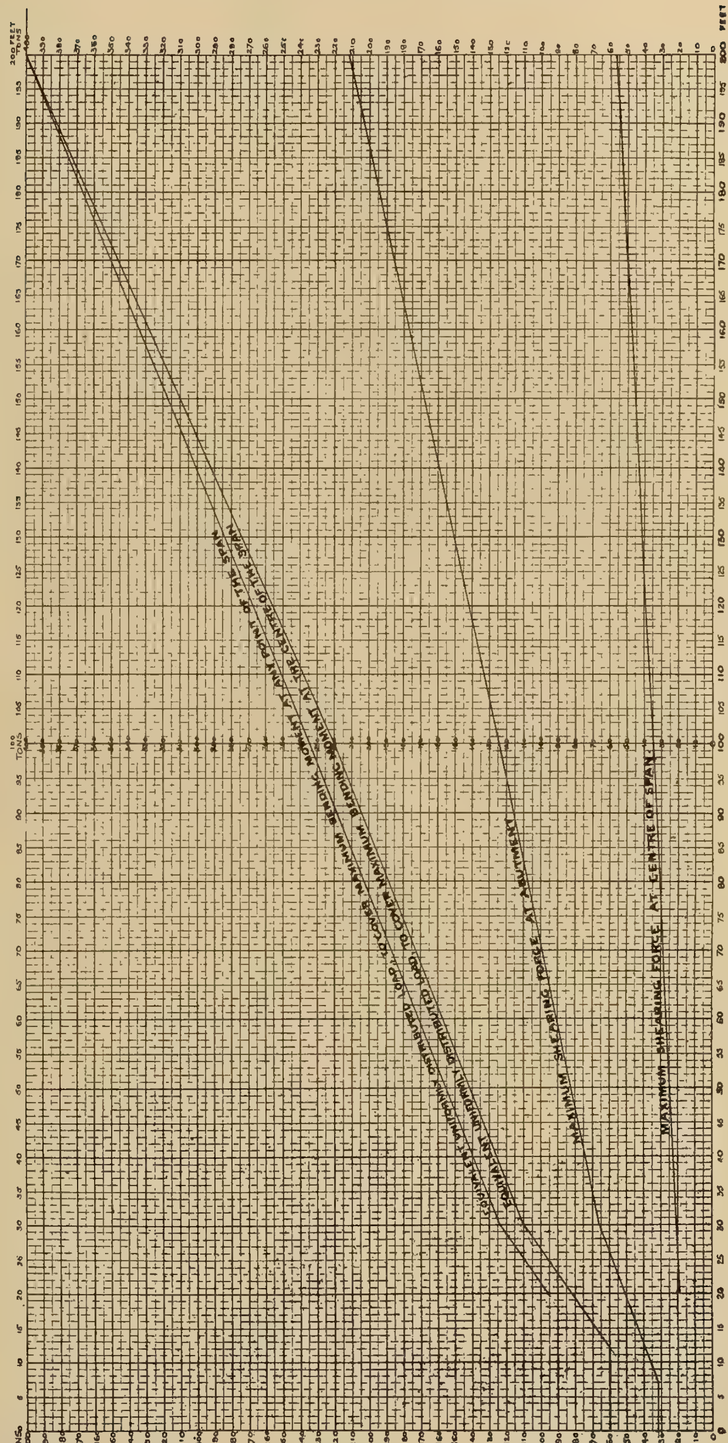
The figures given are assumed to be the maxima for direct tensile or compressive stress, and there is no prescribed limit for either shearing or bearing stresses. It is furthermore not stated whether the live load is to be considered to have the same effect as the same amount of static load, or whether the factor of safety is to be held to include all the effects



CURVES OF IMPACT PERCENTAGES AS COMPILED BY VARIOUS AUTHORS

SUGGESTED SYSTEM OF LOADS ON RAILWAY UNDERBRIDGES INCLUDING PERCENTAGE FOR IMPACT

PER SINGLE TRACK



CURVE OF PERCENTAGE OF IMPACT WHICH IS A MEAN OF THOSE SUGGESTED BY VARIOUS AUTHORITIES

of "impact," or, on the other hand, whether allowance should be made for such effects by increasing the assumed moving loads to obtain an equivalent static load. Considering that it is the custom in America to allow as much as 80 per cent. increase on the assumed live load to cover impact effects, and that 40 or 50 per cent. is recommended by authorities in this country, it is plain that the actual working stresses in the material will depend largely how the Board of Trade regulation is interpreted.

If a factor of safety of 3, after making allowance for impact, is sufficient for cast iron, it is certainly sufficient on the same assumptions for wrought iron and steel, and as a working stress of 6.5 tons for steel gives a factor of safety of between 4 and 5, it would appear reasonable to assume that no addition for impact need be made to the live load used in calculation.

This, however, does not appear to be a correct method of designing girders, since the amount of increase of assumed load is by general consent a variable quantity, which decreases in proportion as the span increases.

The effect of adopting a low working stress for all spans, and neglecting the effects of impact in calculation, would therefore tend to treat unfairly bridges of small span, as the effect of impact and range of stress are both high, compared with those in girders of long span, where a considerable time (comparatively speaking) elapses between the instant that the load begins to be felt and the points when the stress is a maximum; and, further, the stress caused by the moving load is not so large, compared with the maximum and total stress, as in the case of small bridges.

In assuming, therefore, a standard system of bridge calculation, the Board of Trade regulations are of very little assistance or guide on account of their vagueness and incompleteness. Unfortunately they are a restriction in some respects to the economical use of steelwork on account of the rigid rule respecting the working stress of 6.5 tons. In bridges of great span, this is not as serious as in small girders, and the bulk of the bridge work undertaken by railway engineers in England is in connection with small girders of from thirty to a hundred feet in length.

It is hardly open to question that if a high percentage for impact be added to the live load, such as any of those shown in the figure as being used in England, and if every possible combination of locomotives and other vehicles in use on our railways be considered with, perhaps, a small addition to cover future increase, 6.5 tons per square inch is a low stress, considering the nature of the material used. In the Victoria Falls arch, the working stresses were 8 tons in tension and 7 tons in compression, and these stresses would be perfectly safe in any well-designed and well-maintained bridge. If in order to economize in steelwork, and at the same time to comply in appearance at any rate with the Board of Trade regulations, the increase for impact be omitted, the effect is to stress small bridges and parts of bridges, such as cross-girders and longitudinals, more severely than large girders, and bridges are not then consistently designed. When one comes to adopt a percentage for impact, there is great difficulty in deciding which of the many formulæ is correct. The lack of reliable data based on experiment or on scientific theory makes it impossible to devise a scientific and accurate formula. The diagram shown on page 528 shows the difference of opinion on this subject, as expressed in the wide variation of the curves of percentage for impact to be added to the live load plotted from various formulæ. In the curve here shown as that proposed by the author, there is no attempt at inventing a new formula claiming to be more accurate

than those already in existence, but a mean has been taken of those suggested by several authorities in England, and, though this is not the most accurate method of procedure as a general rule, in a case of this kind the result is probably a fair approximation to a suitable formula. At any rate it gives a high increase in the case of longitudinals and short main girders, and a small one in bridges of great span.

In the case of cross-girders, the impact percentage is taken as the same amount as that used for the longitudinals attached to them, which is again a good, if rough and ready, assumption.

Professor Wadell, in his well-known and much-quoted book "De Pontibus," declares that the formula he recommends includes a "factor of ignorance." This is the explanation of the high figures it gives, but unless steelwork is extremely and unusually (for England) badly constructed, the ordinary factor of safety should cover all minor defects of workmanship, such as a loose rivet here and there, and an initially stressed plate. It seems extravagant to allow such a heavy reduction of stress to cover these faults, and if this is done there is no use in taking any particular pains to arrive at the exact loads on the bridge at all, and a very roughly estimated load is sufficient.

Several suggestions have been made from time to time for varying the maximum working stress, or, which comes to the same thing, varying the assumed load; some depend on the span and some on the range of stress. One simple and useful rule (which appears to contravene the Board of Trade regulations), is to neglect the whole of the dead load, and to design the girder for the live load only, using a working stress of about 5 tons per square inch. The effect of this is that the range of stress in all girders is uniformly 5 tons per square inch, and the theoretical maximum stress, excluding the effects of impact, varies from slightly over 5 tons per square inch in the case of small girders, with little dead load, to considerably more—perhaps 8 or 9 tons—in the case of bridges of large span. The actual maximum stress will not vary so much, since it is generally assumed that the effects of impact are larger in small spans than in great. There are, of course, limits to the application of this method, and it is manifestly unsuitable to very large spans where the dead load forms a large proportion of the total load, but for the smaller spans, up to, say, 100 feet, it is a useful and fairly sound rule. The stress of 5 tons on cross-girders is, however, rather high, if only the net axle load be allowed for.

What is very much needed by railway-bridge engineers in connection with this subject is a carefully compiled and standardized system of calculation, including a loading table for girders of all spans, with proper allowance for impact effects, and also the correct working stresses in tension, compression, bearing and shearing. Such a table, though it is not, perhaps, generally applicable, is shown here, and is put forward as a suggestion of what would probably prove useful if universally adopted by British railways. If the various railway engineers would combine to settle the questions affecting working stresses and live loads, and would even make experiments on actual bridges to ascertain the range of stress in the members under different loads at varying speeds, a standard system of calculation might be compiled. The effect would possibly be to raise the present limit of working stress to at least 7½ tons per square inch, which would be a perfectly justifiable step, and also a distinct gain and economy. The factor of safety would still be about 4.

There are a good many directions in which standardization could, with advantage, be introduced, and it would be quite possible for the engineers and locomotive superintend-

ents or mechanical engineers of the various railways in this country to agree upon a certain maximum load or series of loads for locomotives, and also upon a corresponding assumed load for use in the calculation of bridges. There is, as a matter of fact, a very great discrepancy between the theoretical "live load" assumed on some lines and that on others, and since, now-a-days, there are so many running powers over "foreign companies" in existence, and since vehicles, other than locomotives, work practically indiscriminately over any company's lines as required, it seems advisable that there should be some sort of uniformity in the design of railway bridges. This would probably be the very last detail to be considered by two or more companies promoting a scheme for amalgamation or working agreement, but it would be a really important point if one company were considerably below the standard of strength of the others, as far as bridges were concerned, as it would, or should, preclude the unrestricted working of locomotives.

If then, a uniform system of calculation of the strength of bridges of different types, which would still allow of varying detail according to the desire of the designer, and would not interfere with the use of improved methods of construction, were adopted, in time all the bridges in Great Britain would be of uniform strength, and any further increase which might be required in the future (though this is an improbable contingency) would be carried out upon agreed lines and to an agreed extent where considered necessary. At the present time, each railway is independently renewing its bridges as required, to suit its own particular moving loads. Some allow nothing for "impact," and some make a large allowance. Some railways consider locomotives only, and others take all moving vehicles into consideration. In this truly British way a rather chaotic state of affairs exists, and before any new running powers are arranged, it is certainly desirable (though whether this point is ever considered or not the author is not aware) that the loading tables of the two companies concerned should be compared.

In America the assumed loads for bridges have been classified and standardized for years, and it is much to be hoped that something will be done in this way in England. Not only is it important that some degree of uniformity should be obtained, but it would be an advantage for an agreement with locomotive designers to be made, so that the probable limit of their requirements could be ascertained and fixed.

While it is not desirable to attempt an absolute standardization of bridges and girders, it is desirable to standardize methods and assumptions of calculation which should depend on facts, and not merely on opinion. If the facts can be ascertained, and the method and necessary data for calculation decided upon, the individual bridge designer can still have as much scope for inventive faculty as is thought right and proper for him, and is consistent with practical and commercial requirements.

If, however, there are no settled data concerning working stresses and live loads, it is hardly to be expected that bridge design in this country will be of uniform strength either in details or in general features.

LENGTH AND VOLTAGE OF TRANSMISSION LINES

By Alton D. Adams

DISTANCES over which great water powers are transmitted are increasing, though the maximum length of transmission with smaller powers has remained fixed for more than half a decade.

California has been the scene of the longest electric transmissions, both great and small, during more than a decade; but this preeminence in the matter of great powers is slipping away from the olden State, if it has not already departed. For some years the longest transmission of a really great power was, perhaps, that over a line from the Electra plant of 10,000 kilowatts, on the Makelumne River, to San Francisco, a distance of 147 miles. A number of electric transmissions can now be named, however, that surpass the one from Electra in point of capacity, and at least one line delivering a great power surpasses it in length.

Beginning in 1907, a hydro-electric transmission has been operating in California with double the capacity of that between Electra and San Francisco. This transmission begins at a plant of 20,000 kilowatts generator capacity on the Kern River, and ends in Los Angeles, 117 miles away, thus falling short of the earlier system in length of line.

The greatest electric transmission in point of delivered power is, no doubt, that from Niagara Falls to Buffalo, for the two sub-stations that mark the terminals of the five circuits from the Falls contain step-down transformers of no less than 38,250 kilowatts combined capacity in that city, and there is provision for additional transformers to increase this total to 56,250 kilowatts. As far back as 1903 the load on the single sub-station then in use on the Niagara transmission lines in Buffalo was 23,300 horse-power.

Considering both capacity and length, the most notable electric transmission is that between Niagara Falls and Syracuse and Auburn, a total distance of 163 miles. This transmission is now operating with a capacity of 30,000 horse-power, and is delivering power at or near Lockport, Rochester, Syracuse and Auburn; but a portion of the line is designed for 60,000 horse-power. It is said to be the purpose to transmit no less than 180,000 horse-power ultimately to points within reach of Niagara Falls.

Combination of transmission systems in California has brought together lines that extend from Colgate power house, on the Yuba River, to San Francisco, by the way of Oakland and Mission San Jose, a total distance of 222 miles. This power house at Colgate has a capacity of 11,250 kilowatts in generators; but it is uncertain what part of the output is transmitted to San Francisco, as there are more than 100 sub-stations on 1,375 miles of circuit in this system.

Even the above distances are surpassed by the plans for some transmissions now proposed or under con-

struction. One such system, involving both a great power and long transmission, is that of the Stanislaus plant, now nearing completion in Tuolumne County, California, from which a transmission line on steel towers has been run in Tuolumne, Calaveras, San Joaquin, Alameda and Contra Costa counties for the delivery of power to mines and to the cities about San Francisco Bay.

Another large hydro-electric plant to be connected with a long transmission line is the Big Bend, on the Spokane River, 30 miles west of Spokane, Wash., from which 20,000 horse-power will be delivered to the mines and railways in the Cœur d'Alene district, over a circuit 132 miles long. In a list of great powers transmitted long distances should be included the 48,000 horse-power plant in the Urft valley, of West Germany, connected with 103 miles of line at 35,000 volts.

Coming to transmission systems that exist only on paper, one of the most interesting is the suggested development of the Mississippi River at Keokuk, Ia., for an electric plant of 300,000 kilowatts capacity, and the delivery of the output in St. Louis and other cities of the Middle Western United States. The figure of 300,000 kilowatts looks large, even for the Mississippi; but, at all events, there is no doubt power enough in the water at Keokuk to be of much benefit in a section of the country where great hydro-electric plants are now lacking. From Keokuk to St. Louis the distance as the crow flies is about 132 miles, and Chicago is only 217 miles away. Another proposed transmission of water power is that from one or more plants of 115,000 kilowatts total capacity on the river Rhone to Paris, about 275 miles away.

The most striking proposal for the electric transmission of water power is to cross South Africa, from Victoria Falls to Johannesburg and the mining district of the Rand, with a line about 700 miles long. It is said that Victoria Falls are capable of developing 300,000 electric horse-power at all times, and that about 87,000 horse-power is in use along the Rand. Whatever may be thought of this transmission at the present time, the increase of population and of the demand for power in the Transvaal will tend to make more practicable its delivery from the Zambesi.

To carry these larger powers over longer lines the voltages of transmission are being pushed up to higher points, and, what is quite as important, the maximum voltages previously employed on a very few systems are coming into use on many. Higher voltages are being used not only for the delivery of large units of power at particular points, but also for its transmission to numerous points over large systems. Thus, in the great network of transmission lines that traverses some 15,000 square miles of Northern California there are more than 1,000 miles of 60,000-volt circuits, besides 375 miles at lower voltages.

Prior to April 1, 1906, the highest electric pressure in regular use on any transmission line was about 60,000 volts, in the United States at least; but on that date a line 92 miles long between Roger's Dam, on the Muskegon River, and Grand Rapids and Muskegon, Mich., began to operate at 66,000 volts, and this was increased to 72,000 volts within the next few months and has since operated at about that pressure. When first completed, this 72,000-volt line carried only the output of the 3,000-kilowatt plant at Roger's Dam; but a plant of 6,000 kilowatts capacity has since been erected at Croton Dam, on the same river, and connected with this line. From the plant at Croton Dam an additional line, 35 miles long, has been built to Grand Rapids. This 35-mile line operates at 72,000 volts, like the first; but is designed for 100,000 volts.

Other systems now under construction are designed to be operated at

greater pressures, but the 72,000 volts of this Michigan line is believed to be the highest in regular use for power transmission.

The Big Bend system now being built from the Spokane River, at a point 30 miles west of the city of Spokane, into Idaho, a distance of 132 miles, will operate at 80,000 volts. By the time that this matter is in print it is expected that the line from the Stanislaus plant, running through Tuolumne and five other counties of California, will be in operation at 85,000 volts.

While the 117-mile line from the 20,000-kilowatt plant on the Kern River to Los Angeles went into operation at 60,000 volts about the middle of 1907, it and the transformers at the generating plant were designed for 75,000 volts, and this pressure will, no doubt, be made effective when the load makes it desirable.

In the large electric transmission that spreads from the Catawba River over the Piedmont region of North and South Carolina, now operating at 44,000 volts, one trunk line from Great Falls to Spartanburg—about 100 miles long—is designed for 88,000 volts, and will be given that pressure when the load requires it.

Quite as notable as the increase of maximum voltage now going on is the adoption on many systems of voltages that were among the highest five and ten years ago. This turning to higher voltages is found especially where large powers are transmitted and where electric loads are on the increase. A case in point of the latter sort is that of the great transmission system that spreads from San Francisco and San Pablo Bay to the mountains of Northern and Central California, where much of the line formerly built for 10,000 to 23,000 volts has been changed to higher pressures, so that out of 1,375 miles of circuits now in use about 1,000 miles operates at 60,000 volts.

This California system also illustrates the fact that where a number of generating plants are connected to a wide network of transmission lines, though located one hundred to several hundred miles apart, the general use of very high voltage may be desirable for parallel operation; for in this system there are no less than seven water-power plants with a total capacity of 75,000 kilowatts and steam-power plants of about 30,000 kilowatts, all operating in parallel over the 1,000 miles of 60,000-volt line.

Most of the transmission systems that involve more than 5,000 kilowatts delivered at a distance greater than 50 miles are operated at 50,000 volts or more. Where the power is 10,000 kilowatts or more and the distance reaches 100 miles, the voltage in nearly every case is 60,000 or more, and the most recent plants for larger powers and longer distances are designed for voltages between 60,000 and 100,000. Among transmission systems operated with 50,000 to 55,000 volts may be mentioned the three combined plants on the Missouri River, whence power goes to Butte, Helena and Boulder, Mont., the Madison River system in the same State, the Nevada-California plant, the transmission from Taylor's Falls to Minneapolis, the line from Shawinigan Falls to Montreal, the hydro-electric plant on the Iser River and its line to Munich, Bavaria, the Kykelsruth station in Norway, and a part of the system that extends some 200 miles along the Mediterranean coast of France.

Lines designed for or operating at 60,000 or more volts include that from the Muskegon River to Grand Rapids, that between Niagara Falls and Toronto, the line that delivers Niagara power in Syracuse, the circuit under construction from the Rockingham plant on the Yodkin River to Wilmington, N. C.; the lines from the Duero and the Augulo River to Guanguato, Mexico; two circuits from the Kern River to Los Angeles; the line from the Stanislaus plant, in Tuolumne County, California; the transmission east and

west from Post Falls, on the Spokane River, and the line from the Big Bend plant, on the same river, to mines in Idaho.

In the above list are a number of transmission lines less than 70 miles long. Thus, the distance by the line from the generating plant at Roger's Dam, on the Muskegon River, to Grand Rapids is 66 miles; but the operating voltage of 72,000 is the highest now used in the world, though plants for higher voltages are under construction. A voltage of 50,000 is employed on the line between Taylors Falls and Minneapolis, though the distance is 40 miles. From the hydro-electric plant on the Iser to Munich the line is only 30 miles long, and the voltage is 50,000.

Each of the cases just named thus operates with more than 1,000 volts per mile of the transmission, and the Munich line has 1,666 volts per mile. On the other hand, none of the transmission lines more than 70 miles long are able to show as much as 1,000 volts per mile, and on a number of lines over 100 miles long the voltage drops to less than 500 per mile. This falling off in voltage per mile on very long lines is due to a lack of confidence in the ability of insulators to withstand pressures much above those in use, and to the knowledge that loss of energy between wires through the air increases as the voltage goes up where the distance between these wires remains constant.

Improvements in line insulators now promise a large increase of their power to withstand high voltages, and the adoption of steel towers and wooden structures instead of single poles for supports makes it practicable to carry conductors further apart. These improvements and structural changes are the warrant for the general movement to higher and untried voltages on the new lines of great length.

All of this tendency toward increase of voltage is mainly due to the desire to save in the cost of conductors, and incidentally in that of supporting structures. Voltage, load, loss and all other factors being constant, the weight and cost of line conductors increase as the square of the length of the transmission, so that if the length is doubled the weight of wire is multiplied by four.

It would, of course, be desirable, if practicable, to keep the weight of line conductors the same for 100 or more miles as for 25 or 50 miles, where the same amount of power is transmitted, but this practice would quickly lead to unmanageable voltages. Assume, for illustration, that any given power is transmitted 50 miles at a line pressure of 50,000 volts, with a loss of 10 per cent., using a certain size and weight of conductors. To carry an equal power 100 miles, or double the former distance, with the same total weight of conductors, requires four times the former pressure—that is, 200,000 volts—all other factors remaining the same. While the voltage was 1,000 per mile on the 50-mile transmission, it rises to 2,000 per mile on the 100-mile transmission, using the same total weight of conductors.

In view of the known capacity of line insulators and of the air to resist discharges at high pressure, it appears to be quite impracticable to increase voltages in the way just suggested; that is, as the square of the length of the line, starting with the voltages now in common use in transmissions 25 or 50 miles long, so as to require only a constant weight of conductors per unit of power. Another objection to such a ratio of voltage increase, in many cases, is the fact that the fixed weight of metal drawn into conductors of greater length would give conductors too small for the necessary mechanical strength.

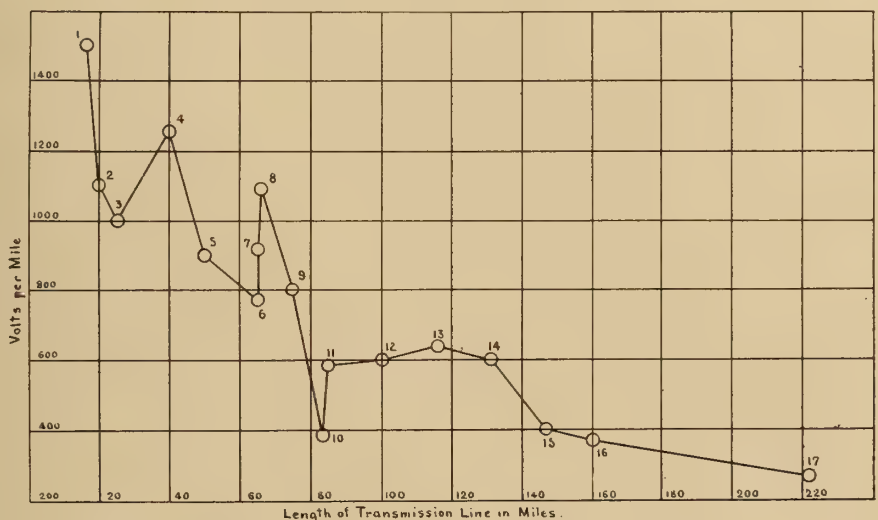
Great impetus would be given to long transmission projects if a voltage of 1,000 per mile, such as is now common on lines less than 60 miles in length, could be maintained on lines one hundred to several hundred

miles long; and there is good prospect that such proportion of voltage to distance will prove practicable for transmissions over more than 100 miles at least.

If the voltage of transmission can be increased directly as the length of line, then the size of conductors will remain constant for a given power, and the weight of conductors will vary directly with the distance traversed, all other conditions being the same. Reverting to the illustration of equal powers transmitted over lines 50 and 100 miles long, respectively, with a loss of 10 per cent. in each case, the size of conductors will be the same in each line, if the 50-mile transmission operates at 50,000 volts and the 100-mile transmission operates at 100,000 volts.

At present the ability to operate with the same voltage per mile of line with length of 100 or more miles that is common on lines less than 60 miles long is the desideratum in electric transmission, but practice is surely moving in this direction.

The more frequent use of voltages from 50,000 to 60,000 on lines only 30 to 50 miles long is due, in large part, to the transmission of greater powers than were formerly common. When only two or three thousand kilowatts is transmitted 30 or 40 miles the highest voltages now in



CURVE OF LENGTH AND VOLTAGE OF TRANSMISSION LINES

LENGTH AND VOLTAGE OF TRANSMISSION LINES.

Location of Line.	No. on Curve.	Length in Miles.	Total Volts.	Volts per Mile.
Chambly to Montreal	1	16.6	25,000	1,500
Niagara Falls to Buffalo	2	20	22,000	1,100
Apple River to St. Paul	3	25	25,000	1,000
Taylors Falls to Minneapolis	4	40	50,000	1,250
Fossil Creek to Prescott	5	50	45,000	900
Conor Ferry to Butte	6	65	50,000	770
Conor Ferry to Winnipeg	7	65	60,000	920
Muskegon River to Grand Rapids	8	66	72,000	1,090
Niagara Falls to Toronto	9	75	60,000	800
Santa Ana River to Los Angeles	10	83	33,000	390
Shawinigan Falls to Montreal	11	85	50,000	590
Duero River to Guanguato	12	100	60,000	600
Kern River to Los Angeles	13	117	75,000	640
Big Bend, Spokane River, to Idaho	14	132	80,000	600
Electra to San Francisco	15	147	60,000	400
Niagara Falls to Syracuse	16	160	60,000	370
Colgate to San Francisco	17	222	60,000	270

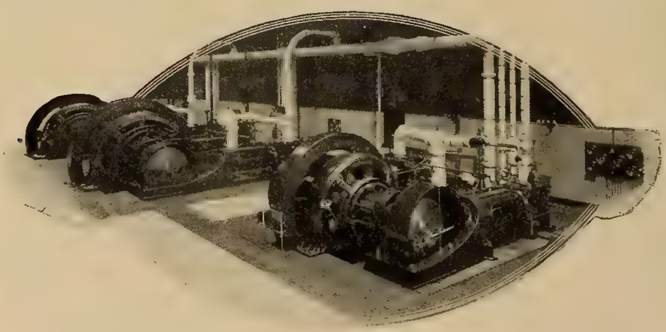
common use may call for conductors too small to give the necessary mechanical strength; but if the power be increased to 10,000 or more kilowatts, these same voltages may require conductors of ample size and still effect a large saving in weight.

For voltages of 50,000 or 60,000 the cost of transformers, switches and line insulators is materially higher than for voltages of 30,000 to 40,000, and the cost of line structures is also somewhat higher in the former case. With a small power the excess cost of transformers, switches, insulators and line structures for the higher voltages may more than offset any saving in the weight of conductors; but as the power increases the cost of conductors becomes the most important item.

As the amounts of power involved in transmissions 20 to 50 miles long increase, there is sure to be a much wider adoption of voltages between 50,000 and 60,000, which are now quite manageable in practice, while large powers over distances of 100 miles and more will be the field for the higher untried voltages.

The table and curve herewith show the length in miles, total volts and volts per mile for seventeen of the more important transmission lines in North America. Perhaps the most notable fact here illustrated is the drop from 1,500 volts per mile on the lines between Chambly and Montreal to only 270 volts per mile on the line between Colgate power house and San Francisco. Extremes of practice are shown by the Chambly, Taylors Falls and Muskegon lines, on the one hand, and the Apple River, Canon Ferry and Santa Ana lines on the other.

As a rule, it may be noted that the more recent plants have the higher voltages.



DEPRECIATION

By A. Winder

DEPRECIATION is made up of two elements of loss, namely, obsolescence and deterioration.

Obsolescence implies growing out of date as a profit maker. It is quite independent of the volume of work a machine has done. A new thing may be obsolete.

Deterioration implies loss of value, loss of newness, due to use. The parts of a machine suffer when they are used and the rapidity of deterioration bears some relation to the volume of work done.

Depreciation, then, comprises two elements which cannot satisfactorily be combined. For instance, when a machine tool is worked night and day its liability to be superseded (obsolescence) by a superior tool is not increased, but its life is being shortened (deterioration) at an increased speed by reason of the tool being made to do double duty.

Obsolescence. Fashions do not occupy such a prominent place in the engineering industry that one need give it a place in a short paper of this kind. When we speak of obsolescence, therefore, we confine ourselves to profit-making considerations only.

A tool may be as capable to-day as it was thirty years ago of doing a certain quantity of work per annum, but if it has been superseded by a competitor's tool, capable of doing more or superior work, then it no longer holds its old place as a profit-maker, for the obvious reason that it can no longer compete successfully.

It is possible, but fortunately it is very improbable, that all our appliances of to-day may be totally eclipsed by the inventions of to-morrow; we have such faith in the improbability that we consider one tool may be good for 10 years, another for 20 years, and yet another possibly for 30 years.

In the case of machine tools this is a question which calls for most careful consideration, and a liberal estimate of the provision it is advisable to make for obsolescence.

This subject has, perhaps, not always received the attention it deserves from buyers of tools and equipment. Plainly, however, it is wiser to buy a tool which has some reserve of strength, or power, or speed, than to buy one which is likely to become more or less obsolete as soon as some improvement is invented. The obsolescence charge for the latter must of necessity be heavier.

In fixing the probable period of "youth" of a machine, regard must be had to the chances of disposing of the tool for a price somewhat better than scrap value. There are many small businesses which have not sufficient work to keep certain tools fully occupied, and they prefer to purchase something equal to their requirements at a price considerably less than that of the latest type.

When improvements are announced the question arises as to what is to be done in the way of disposing of present equipment and installing the most modern. If on inspection the latter appears to justify its existence and to offer means of cheapening production, then it may be advisable promptly to set aside more ample obsolescence in the case of the appliances superseded by the new invention.

Deterioration. The rate at which

various classes of equipment deteriorate varies with each class and each unit, and attempts to reduce them to a uniform rate are foredoomed to failure. Each class must be considered on its own merits, and in the case of large units, such as machine tools and motors, each item requires individual consideration.

Take, for instance, two machine tools of similar capacity and power, but by different makers. One is designed so that it can, at relatively small cost, be brought practically up to a condition of newness. The duration of life of that machine is very different from that of the second machine, which is not equally susceptible of rejuvenescence. The latter requires greater provision for deterioration because its life cannot be prolonged equally with the first one.

The second machine may have cost a few pounds less than the first, but is it doubtful whether money saved at the expense of life is profitable—it costs something every year in increased deterioration charges.

Year by year, in fixing the amounts to be written off for obsolescence and deterioration, individual circumstances should be given due weight. As has already been mentioned, a new invention may involve an increased charge for obsolesence. Similarly with deterioration, a serious accident to a tool may shorten its life because of the nature of the breakage and the feasibility of effecting a relatively permanent repair.

These suggestions appear to involve much clerical labour and to call for the expenditure of much time by the management. But it is not so to an unreasonable or unprofitable degree.

Managers generally keep themselves informed of the advances and improvements continually being made. If a note is made in the depreciation book as such improvements are made, the readjustment of obsolescence charges is made a very simple matter.

Then, with regard to deterioration reserves similar notes may be made of any event likely to shorten the life of the equipment. The cost of each item in repairs during the year should also be taken into account. Not infrequently a time arrives when it is economical to scrap an appliance which is a source of continual and relatively great expense.

Each item of equipment should bear a serial number painted cr stamped on the article itself. This number would be taken from a depreciation book.

The depreciation books shows the particulars of the equipment, the first cost, the serial number and the estimated rates of obsolescence and deterioration. After these particulars are several cash columns showing the reduced value year after year, so that several years' figures appear at one opening.

Current Topics

ONE of the great difficulties of the legislative mind lies in its inability to accommodate itself to immediate conditions. The "dead hand" has its grasp firmly about official action, and it is with difficulty loosened, and with much reluctance cast aside.

This is plainly evident when the question of dealing with regulations concerning motor vehicles on common roads is considered. It is evident to every observant individual that the automobile is the vehicle of the immediate future, and, in fact, is practically the vehicle of to-day. This being accepted, it should be conceded that the highways upon which vehicles are to be run should be constructed in such a manner as to serve the purpose for which they are principally to be used. Under such circumstances, the question as to the proper surfacing for modern roads seems to be a matter for investigation in the light of present conditions, and any attempt to regulate road making upon the old lines by restricting the speed, weight, or construction of automobiles must ultimately fail. The road engineer must first of all consider what service is required of the highway, whether it be city street or country road, and no one who watches a well-traveled road to-day can fail to realize that the new conditions demand modifications in the surfacing at least, if not in the substructure.

It can easily be understood that much of the wear on the ordinary road has hitherto been due to the pounding action of the hoofs of the horses, and, indeed, wheeled vehicles having wide tires were considered as partaking somewhat of the nature of road rollers, improving the surface of the highway by compacting the material. The automobile, on the contrary, acts to loosen the surface of the road, both by reason of the oblique pressure of the driving wheels of the machine, and by the suction of the rubber tires, lifting loose stones, raising dust, and generally disintegrating a roadway which might well have sustained ordinary vehicular traffic without injury.

Since the automobile must inevitably continue to be operated upon our streets and highways, and the number of mechanically-propelled vehicles increase rather than diminish, it is absurd to deplore the injury to the old-fashioned road; rather should the engineer devote some portion of his attention to the real action of the motor car upon the road, with a view to such modifications as will meet the new conditions.

At the present time the best lines along which modifications in road construction may be made to meet the action of the powerful automobile driving wheel are by no means determined, and it is probable that exhaustive experiments will be required to determine the modifications necessary in order that the full advantages of mechanical propulsion may be realized without destructive effects upon the highway.

Apparently it is high speeds which have the most injurious influence on roads of present types; and the slowly moving motor truck, or even the touring car which does not aspire to maximum velocity, produces but little injury to the road. Nevertheless it appears that the development of automobile traffic in a country having such admirable roads as France has resulted in halving the time required for resurfacing the highways, and this is ample evidence that some improvement in road making must be developed to meet this doubled wear and tear.

The scientific method of meeting the question is that of studying carefully the exact effects of machines of various kinds upon existing roads, including the influence of weight, speed, tires, and other operative elements, thus gathering accurate information, and placing the whole question upon a precise basis, free from the influence of individual opinion and prejudice, rendering a satisfactory solution practicable.

THREE months ago a number of Americans who build and manufacture material and equipment for railroads came together in New York and organized the Railway Business Association.

They undertook to restore smoke to extinct chimneys, work to idle men, purchasing power to myriad of American consumers. The plan was to tell the American people that the railroads are their railroads, efficient transportation service their service, new mileage an advance agent of prosperity, improvement of established lines the handmaiden of commercial expansion; that necessary regulation of railway corporations had been attended with so much of threat and outcry and denunciation that holders of capital had become frightened as to the effect of legislation upon railway securities, and were now hesitating to lend money for transportation enterprises.

In three short months the average American business man as represented in his local board of trade has expressed himself in a score of resolutions urging Congress and the Legislatures not to relax regulation; not to "let railroads alone;" not to abandon the shipper or the consumer; but to approach the restriction of a railroad calmly, without prejudice, carefully investigating the conditions, and making sure that the railroad will have means for meeting the cost of what is imposed upon it, and ascertaining with reasonable definiteness that the measure proposed will accomplish the reform desired.

It has been stated that among others the Board of Commerce in the city of Detroit, by which such a resolution was adopted, was urged to do so in no other way than by means of a printed circular; this indicating the readiness of American business men to subscribe to the doctrine of moderation in the restriction of railroads, and showing that if some law givers had believed business men universally approved of indiscriminate attacks upon railroads they were mistaken. The Detroit resolution, which is the shortest of those adopted, is also ideal in its completeness: "Resolved, That it is the sense of this Board that State and National Legislators, in view of the immediate necessity for stable conditions of finance and business, should exercise moderation and calmness in legislation affecting public service and

other business corporations." In this and other practical ways business men have been led to memorialize their representatives in Congress and in the Legislatures.

The Railway Business Association has crystallized business sentiment in a form which makes it palpable to the legislative eye. This in itself is glad tidings to the managers of railroads, which they are acknowledging with enthusiasm. When the results shall have presently become palpable in the form of wise legislative action, we have no doubt the association will devise means for bringing them under the eye of the investor.

When in the history of industry and finance has a body of men chosen a task more sagaciously, or performed it more effectively? When have the unshackled forces of democracy, from which so much is feared, been so notably instructed in elementary economics, reduced to the terms of individual self-interest?

The work of this group of Americans, begun three months ago, is not finished. Much remains to be done. Perhaps they will find a place among the permanent agencies of civilization. But those most in interest regard the labour already performed as a memorable achievement, and a place on the membership roll of the organization a certificate of very great usefulness to the railroads, to all the cognate industries and to the nation.

MANY years ago the relation of possible aerial navigation to certain economic questions was discussed in an academic manner, especially as regards the practicability of enforcing customs regulations, and it was suggested that as soon as the practicable air ship made its appearance the era of universal free trade would necessarily follow.

The matter is an interesting one for many reasons. The old law that real property rights extended down to the middle of the earth, and up to the heavens, was formulated when the ability to occupy these extremes was very limited, and it remains to be seen whether ownership can be maintained in localities in which effective occupancy cannot be held. This is especially true of national domain, and if we accept the definition that property is that which one is able to defend, the domain of the air is held by a very uncertain tenure.

That the owner of lands and buildings should be protected from invasion from any passing aeroplane or dirigible must be accepted, and while it does not precisely appear how a machine can be prevented from passing high above a house, it seems as if the aerial navigator may well be held liable for any trespass which he may commit in descending.

Students of history of property rights have found interest in reviewing the gradual development of ownership in land, while the extent and limitations of property rights in water have formed a further subject for study, in view of the physical differences between the land and the ocean. Now, with the advent of space-telegraphy and of aerial navigation, enabling almost anyone to send messages over landmarks and national boundaries without stringing visible wires; or of passing high over lands and cities, arsenals and fortifications without let or hindrance, the whole question as to what constitutes real ownership comes up anew.

In the international conferences which have been held to consider the regulation of space-telegraphy it has been ruled that the air is free, so far as its use in connection with the transmission of messages is concerned.

It seems as if any attempts to control the movements of flying machines in the air above private or national property will have to be considered upon much the same basis, at least until some effective method of aerial police regulation can be effected, so that the whole question is indeed "in the air," and from present appearance it is probable that it will remain so for some time to come.

CHARLES H. MANNING

By William Ledyard Cathcart

A BIOGRAPHICAL SKETCH

THE wisdom of the provisions of the Personnel Law of 1898, by which engineering was made a part of the duties of the line of the navy without also establishing a corps of engineer specialists in that branch, is still a mooted point. As to one effect of this change, however, there can be no question—the deep regret with which many, within and without the service, have viewed the passing of the Engineer Corps from our naval organization, since its ideals were high, its achievement was great, and it had a long roll of honor.

Looking backward through the years, one readily recalls such engineer officers as Haswell, Isherwood, Loring, Melville, Manning, Kafer, Thurston and others, of the living and the dead, who, in their day, not only wrought nobly for the advancement of science, but also fought sturdily within the Navy Department, and, through their representatives, in the halls of Congress, at a time when marine engineering was struggling for adequate recognition in our navy.

Charles Henry Manning was born in Baltimore, Md., on June 9, 1844. He is the son of Joseph Cogswell Manning and Rebecca Parkman Jarvis (Livermore) Manning, and comes from old New England stock, being the descendant, in the ninth generation, of William Manning, who settled in Cambridge, Mass., in 1634, and whose land there remained in the Manning family for more than two hundred and thirty years thereafter. In 1871 Captain Manning was married to Miss Fanny Bartlett, of Boston, Mass., the sister of Major-General William F. Bartlett, one of the most gallant men sent by Massachusetts to the Civil War.

Manning's father was for many years a prominent iron merchant of Baltimore, owning and operating the Avalon Nail & Iron Works there. Manning received his early education in private schools in Baltimore and in the High School of Cambridge, Mass.; in 1860 he entered the Lawrence Scientific School of Harvard University to study civil engineering. After the fall of Fort Sumter he joined the drill club which guarded the State Arsenal at Cambridge, and later was offered a lieutenancy in a Massachusetts regiment, which, because of his youth and for other reasons, his father would not permit him to accept.

Owing to business reverses brought on by the war, Manning returned to Baltimore in the autumn of 1861, and, following his natural bent, entered as an apprentice the marine engine works of Charles Reeder, where, in working on naval vessels, he met a number of engineer officers. Contact with them gave his active energies a definite aim, and, as a result, he was appointed a Third Assistant Engineer in the Navy on Feburary 19, 1863, having passed third in the class of sixteen of that date. He was, however, to see relatively little service under fire, since Engineer-in-Chief Isherwood, recognizing his worth as a scientific observer, kept him closely occupied with the classic experiments on superheating in the *Adelaide* and other vessels, thus limiting his experience of actual naval war to some brief fighting in Hampton Roads and to a passage in convoy of troops during the siege of Charleston.

Manning served on the *Adelaide* for two years, and left her in March, 1865, for the sloop-of-war *Dacotah*,

to which vessel he was attached until September, 1868, making in her the circuit of South America and cruising as far north as Panama. The outward passage was noteworthy for the company of the Peruvian iron-clads *Independencia* and *Huascar* from Rio de Janeiro onward, since the latter vessel was to become memorable in naval history for her heroic fight in the subsequent war with Chili. The *Dacotah* was also at Valparaiso during the great earthquake of August, 1868, and the next day left for Arica, where 10,000 lives had been lost, and the U. S. S. *Wateree*—an iron double-ender—had been washed a mile inland and left there on an even keel. From the *Dakotah* Manning was ordered to the sloop-of-war *Seminole*, which cruised on the home station, mainly in West Indian waters, until February, 1870, when she returned to New York with yellow fever on board and was put out of commission. From September, 1875, to September, 1877, he served on the sloop-of-war *Swatara*, and from September, 1880, to August, 1882, on the Presidential yacht *Despatch*—in both cases on the home station. With the latter duty his service at sea ended.

Owing to his marked ability as an instructor, Manning's shore duty was passed wholly at the Naval Academy, where he was stationed for five years, beginning with September, 1870, and again for three years from September, 1877, onward. During the first of these tours of duty he aided in organizing the course of instruction for cadet engineers at the Academy. His service in this the veteran engineer characterizes as "the most valuable work I have ever done," an estimate which, without disparagement of his achievement in other fields, will meet full agreement from those who know the far-reaching effect of that course on the advancement of the science of marine and mechanical engineering in the United States, an indication of which is given by the fact that, among its graduates, are the professors of mechanical engineering in Harvard, Pennsylvania, Michigan and Stanford Universities.

This course was originally established by Congress in 1864; but the project languished until 1871, when the first class of sixteen members was admitted to the Academy. Yearly thereafter twenty-five cadets were appointed until 1882, when, in the full tide of success, it was abolished by act of Congress, and the cadet engineers then at the Academy were transferred as cadet midshipmen to the line of the navy. The course met thus its sudden ending because of its very success, and that success was the result primarily of two conditions: first, its instructors were picked men, the ablest in the Engineer Corps; second, its cadets were selected by competitive examinations, so severe eventually that most of the successful candidates came from colleges or universities.

The natural result of this system was the formation of a body of students who, in ability and scientific training, could not but be superior, as a whole, to the cadet midshipmen who were then, as a rule, appointed by political influence. The contrast between the two courses was sharply shown when, in 1882, the cadet engineers were transferred to the corresponding classes of cadet midshipmen. In his work, "The Steam Navy of the United States," Commander Bennett says:

> A year after the exchange was made we find that seven of the first ten members of the graduating class were former cadet engineers, and four of the six "stars" (honor men) of that class were engineers. * * * In the next class the three leading members were former cadet engineers. * * * In the third class, after the amalgamation took place, * * * we find that thirteen of the first fifteen members, nine of the first ten, and all six of the "stars" were former cadet engineers.

It is not strange that, with the inevitable and rapid progress of engineering in naval science, far-seeing line officers dreaded the effect of such a system of engineering education upon the prestige of their branch of the service, and that, through their influence, the change was made. One of them, when asked why the course had been abolished, said frankly:

"We had to. They would have crowded us off our ships."

For the exceptional standards of this course the navy and the cause of technical education in the United States owe a debt, primarily and pre-eminently, to two men: Charles H. Manning and the lamented John C. Kafer. While other officers laboured ably and faithfully in its routine work, Manning and Kafer, with their high ideals and their wide attainments, left on it an impress which marked it to the end, and which has been borne always in grateful memory by its graduates.

In 1881, while attached to the *Despatch,* Manning served as a member of the first Advisory Board, the body which prescribed the general characteristics of the first vessels of the new navy. This Board consisted of thirteen officers of the line, Engineer and Construction Corps, its president being Rear-Admiral John Rodgers, than whom no nobler man ever trod a deck. The engineer members, in addition to Manning, were Chief Engineers Benjamin F. Isherwood and Charles H. Loring. In preparing the machinery plans for these vessels, Manning's instinct as a designer—which leads him by the shortest path, even if it shall pass over hitherto untrodden ground—was continuously exercised. In one noteworthy step of the Board's action—the decision to build the hulls of the new vessels of steel—he cast the deciding vote, the Board standing 7 to 6, and Manning being the only engineer who, in the existing condition of the art of steel-making in the United States, was willing to take the responsibility of voting for that metal.

Manning's service to his corps, in seeking by all just means its rightful recognition, began early, as might have been expected from his determined character, and was continuous throughout his years of active duty. The line and staff feud of those old days was a relentless strife, the bitterness of which it is difficult to realize fully at this time; and its warriors on the staff side were marked men, who needed high courage, strong wills and much shrewdness to escape unscathed. Two incidents which may be cited will show Manning's boldness in forcing justice to his corps.

A bill had been rushed through, without due consideration, in the closing days of Congress, abolishing the grade of Third Assistant Engineer. If this measure had become a law, its effect would have been to drop summarily these officers from the navy, wherever they might be stationed, "from China to Peru," without even an allowance for traveling expenses to their homes. By unremitting effort, Manning, through a friend, brought the bill to the indignant attention of President Johnson on the last day of the latter's term of office. The President said: "This measure will become a law to-day, with or without my signature. There is but one thing to do," and, with his own hands, he tore the bill in two and threw the fragments into a fire blazing in an open grate in his office at the White House. With Congress on the verge of adjournment and the only legal copy of the bill thus destroyed, the threatened officers were saved to the navy.

Shortly after, Manning was informed by the chairman of the Naval Committee of the Senate that that body would confirm the appointments of certain engineer officers if their nominations were sent in at once by the Navy Department, but that a further delay would be dangerous. He called upon the Secretary of the Navy immediately and stated the case. The Secretary, new to his office, sent for Admiral Porter, who, at that time, was virtually supreme in naval affairs. The Admiral, eager to defeat the nominations, advised against them; but Manning, in his presence, presented such a forcible argument to the Secretary that, despite the Admiral's opposition, the nominations were sent in and promptly

confirmed. Only those familiar with naval customs can understand fully the boldness of a young officer of twenty-five in thus antagonizing the Admiral of the Navy. Such temerity could have, in those days, but one result—a prompt cruise to the torrid West Indies, to which Manning was shortly ordered.

It is pleasant to note that Admiral Porter, while a relentless enemy with an unfading memory, had a manly respect for a worthy foeman. Years after, recognizing Manning on the *Despatch,* he came to the engineer officer and entered into a long and pleasant conversation, as if there never had been war between them.

In May, 1884, Manning was placed on the retired list of the navy, owing to a partial loss of hearing, due, as the medical board reported, to exposure "in the line of duty." The retirement of such an officer, otherwise in the full vigor of manhood, was a most serious loss to his corps and the navy, a view which Chief Engineer Isherwood expressed in an appreciative letter to him, and which Rear-Admiral John L. Worden, who had commanded the *Monitor* in her engagements with the *Merrimac,* and who was then the president of the Retiring Board, also held, since he said to Manning: "I would rather see any other man in your corps go."

In August, 1882, Manning was granted a year's leave of absence, after twelve years of continuous duty. This leave was given, that he might accept the position of mechanical engineer of the Amoskeag Manufacturing Company, of Manchester, N. H., with which company he has remained continuously since, subsequently becoming general superintendent. This company operates the largest cotton mill in the world, its land and buildings extending in an almost unbroken line on both sides of the Merrimac River for a mile and a half. As superintendent, Captain Manning has charge of the power plant and the building and grounds, and, in addition, is the architect and builder of new mills as they are erected. The extent of these duties may be best measured by the following statistics: Floor space in mills, 110 acres; water turbines, 16,488 horse-power; steam turbines and engines, 22,900 horse-power; hands employed, 13,000; number of spindles, 600,000; number of looms, 20,000; yards of cloth woven per week, cotton, 4,000,000; worsted, 400,000. A new mill is now building which will increase the product to a million yards of cloth a day, the number of hands to 15,000, and the horse-power to 30,000, developed by water and steam.

These mills show throughout the traces of Captain Manning's skill as an engineer and organizer. In the beginning of his service he re-assembled the boiler plant after a plan striking in its boldness. The scattered units were gathered into groups near the coal pile, a steam pipe was laid across the river, and, in one case, steam was led through a pipe nearly half a mile long. Then he designed the Manning boiler, of which 146 are in service at the Amoskeag Mills, and which is used in textile manufacturing in New England to a greater extent than any other type. In 1885 he was an engineering pioneer in designing and building there the first large installation (2,000 horse-power) of water turbines on a horizontal shaft. The fall of water was 47 feet, and critics asserted that the sidewise thrust on the wheels would affect their successful operation. They, however, ran smoothly from the beginning. In 1891 a flywheel, 30 feet in diameter and running at 60 revolutions, burst in one of these mills, the cause being a defective casting, since the wheel was at but little above its normal speed. Manning replaced it with his historic "wooden flywheel," an iron wheel with a rim built up almost wholly of wood. This also has run without failure since its erection.

When the Greely Relief Expedition was organized, Admiral (then Chief Engineer) Melville selected

Manning as chief engineer of one of the relief ships; but the then Secretary of the Navy—a New Hampshire man—decided that, in view of his responsibilities, he should remain at Manchester.

Manning's service during the Spanish-American war proved the sterling quality of his patriotism, as a consideration of the circumstances will show. Thus, it was known to all well-informed officers that the naval fighting in that war could be but brief and relatively unimportant, since our force on the sea was overwhelmingly superior to that of Spain. Again, Manning was fifty-four years of age, his business responsibilities were great, and he had the strongest political and naval influence, since both the Secretary of the Navy and the Engineer-in-Chief were his personal friends. Under these conditions, many retired officers of his age would have been tempted to seek an assignment to relatively light inspecting duty near their homes. Not so with Manning. There was important work to be done at the Key West naval station, in the repair of the machinery of the many warships which gathered there. Owing to the torrid climate, there was no more unpleasant shore duty for a naval officer; but when Manning was asked to go there as chief engineer, he went without question, and spent the summer toiling in the stifling heat, glad to serve the flag again.

In correspondence with the writer, Rear-Admiral Melville, formerly Engineer-in-Chief of the navy, says:

> How fast the men of the old Engineer Corps are fading! There are left now but few of that bright galaxy—Kafer, Manning, Thurston, West, and a half score of others—who established the course for cadet engineers. To my mind, the ablest and most levelheaded of them all was Manning. He was big in every way—in build and brain and heart.
>
> During the Spanish-American war the Navy Department was disturbed by the unusual number of ships which were laid up for repairs at Key West. For various reasons the situation at that station was difficult to handle. As engineer-in-chief, I tried several engineer officers there, giving them an abundance of tools and material, but the ships still lingered. Finally, I sent Manning there, and the atmosphere of delay cleared quickly. He put no extra polish or finish on the work, but all that tended to efficiency of the machinery was done, and done promptly, and, through his tact and energy, the ships were soon despatched to their stations on the southern side of the island of Cuba.

Captain Manning has been active in civic duties. He was a member of the New Hampshire Constitutional Convention of 1886, and has been a member of the engineering committee of the Board of Visitors of Harvard University for many years. In his home city he was for eighteen years on the School Board, and has been president of the Water Board for ten years. In addition to his work for the Amoskeag Company, he acts as consulting engineer for several other large mills, and is regarded as an authority on water rights.

He is a Past Vice-Commander of the Military Order of the Loyal Legion and a Past Vice-President of the American Society of Mechanical Engineers. Harvard University conferred on him the degree of Bachelor of Science, as of his old class of 1862, at the Commencement in 1895. He is a member of the Army and Navy Club of New York, and of the American Society of Naval Engineers, the United States Naval Institute, American Society of Naval Architects and Marine Engineers, American Association for the Advancement of Science, and American Society of Cotton Manufacturers.

In closing this brief sketch, the writer feels that it records but inadequately the forceful and brilliant career of the gallant officer who was his instructor and friend in years gone by. Every inch a man, and in every fibre an engineer, Captain Manning, in his long service, has not only honored his profession and the navy, but his manly and generous nature has won for him as well a return which, when all is said, is better still—the deep respect and the warm friendship of many men.

AUGUSTE RATEAU

Professor at the École des Mìnes, Paris

See page 644.

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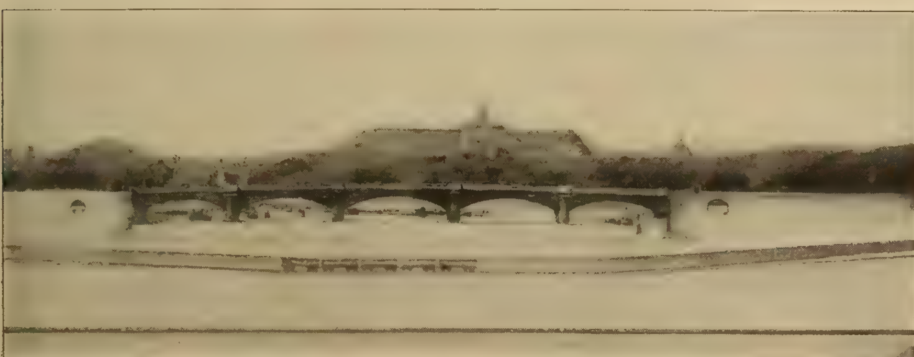
UNDERGROUND RAILWAY CONSTRUCTION IN PARIS

By A. J. Thompson

Visitors to the Paris Exposition of 1900 will recall the interest which was aroused by the opening of the first portion of the Metropolitain, the underground railway which, with its extensions, has done so much to make travel to various parts of the French metropolis rapid and convenient. Ever since the year of the Exposition the development of the Paris subway system has gone on, and in the present article Mr. Thompson describes the construction of the most recent portions, involving some interesting work in reinforced concrete and in subaqueous tunnelling.—THE EDITOR.



TUNNEL UNDER THE RIVER SEINE. NORTH-SOUTH LINE OF PARIS SUBWAY

IN none of the large cities of Europe has the question of rapid transit been solved in such a satisfactory way as at Paris, especially as regards the development of the subway system. The present lines of subway, of which there are a number in operation, are well patronized by the public, and at present there are various new lines in construction. As to the total length of subway line which is actually running in regular service, it is about 25 miles. This, however, is but a part of the extensive system which is now in preparation, and this will be somewhat more than 70 miles when the present plans are completed, which will be within a few years. At that time the city will be very well covered by the subway lines. Estimating the zone on each side of the line within which it is patronized by the public to be 1,300 feet, nearly the whole area of the city will be covered by the zones corresponding to the subway lines, leaving but a few blank spaces. In this way Paris, which has for so long a time been deprived of

good rapid transit facilities, will, undoubtedly, be the best provided in Europe in this respect.

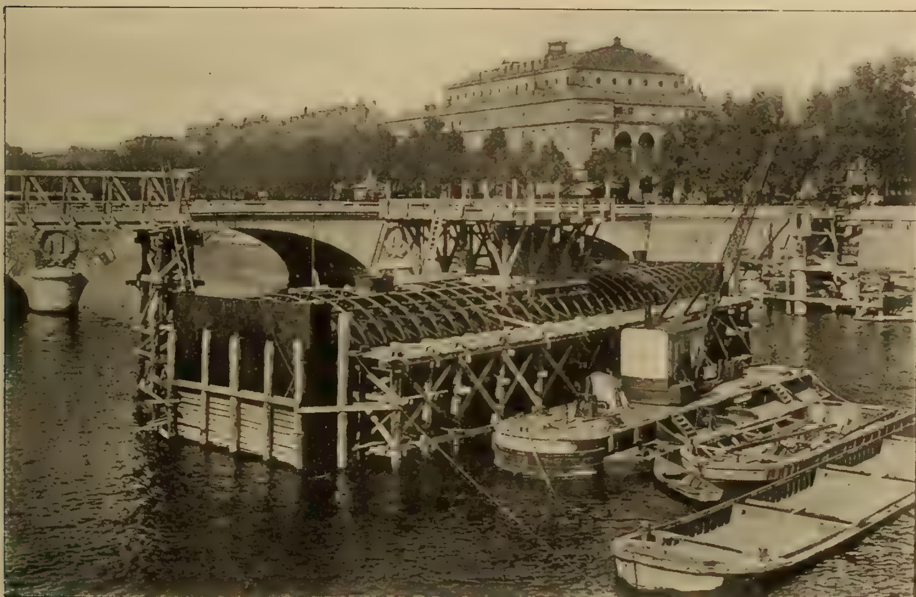
We wish to speak at present of some of the points about the new underground lines which present some original features. Within a recent period there have been also finished a number of new sections of subway. Regarding the finished portions, which are now running or are shortly to be opened for traffic, these lines run principally in tunnels, but there are depressions in the ground over large areas which made an overhead structure necessary for a considerable length. This is true of the regions near the Seine, and at the present time the lines cross the river upon three different bridges. One of the bridges, which is represented here, is the Passy Viaduct, which was built especially for the Metropolitan line, and has about 610 feet length, exclusive of the approaches. The first platform of the bridge serves as a wagon road, with foot walks, and upon this is built a second structure, which serves for the electric road.

At another part of the Seine was built a new bridge where the line crosses the river near the station of the Orleans Railway. It has a span of 460 feet and is used exclusively for the Metropolitan tracks. A third bridge was required not far from the latter, and in this case the Bercy Bridge, a masonry structure of old date, was enlarged in order to receive the tracks. In all these cases it was an easy matter to cross the Seine by means of the bridges, so that there was no special difficulty encountered here. The reverse is true as regards the new subway lines which are in course of construction, and there are three underground lines building at present which are obliged to make the crossing under the river, as they lie in the central districts where additional bridge building would not be allowed. Of the three lines in question, two of them will cross under the river by means of a tunnel formed by sinking metallic caissons in the river bed. The third line, on the contrary, has adopted the tube system, the tube

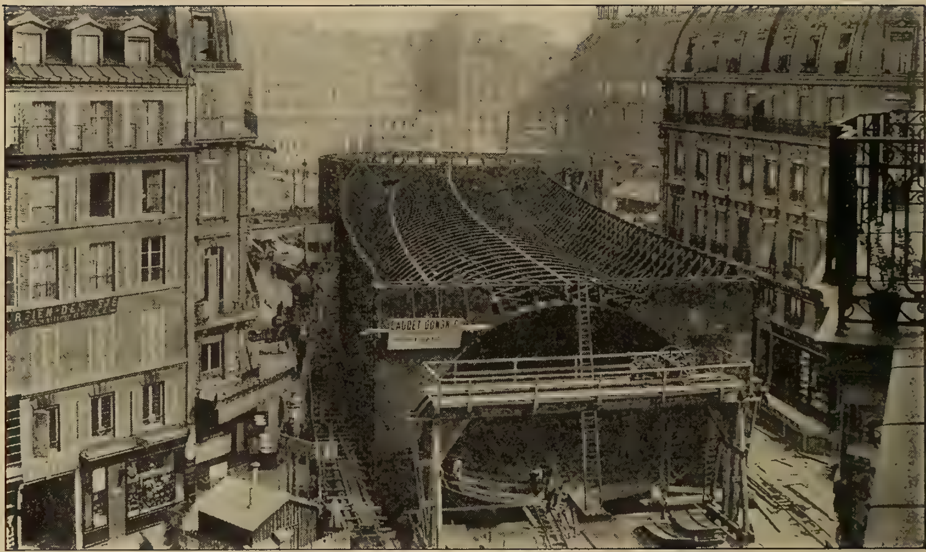
VIEW OF THE PASSY VIADUCT. METROPOLITAN LINE

being placed by the compressed-air shield method. We will give a brief account of the different methods of construction which have been adopted in these cases.

The first of these lines is the subway which crosses the city from the Porte de Clignan Court to the Porte d'Orleans, running in a general north and south direction, but in a somewhat irregular course, this being made necessary by the passage of the line under the different streets and boulevards. It is built entirely underground, having a total length of about 6 miles. What is worthy of note about the present line is, that part of it crosses under the Seine, as in this case the subway makes the crossing in the central part of town, and for esthetic and other reasons the authorities would not allow of building a bridge in this part of the Seine. Where the line is obliged to cross the river, the latter has an increased width, owing to the presence of the Ile de la Cité, containing Notre Dame and other buildings. It was decided to use the method of sinking metallic caissons in the bed of the river in order to construct the tunnel. Besides this, there are two underground stations in the part of the subway which had also to be built of metallic caissons, owing to their proximity to the Seine. One of the stations lies in the Ile de la Cité and the other on the south bank at Place St. Michel. In this way the work in this part of the subway required the sinking of eleven large caissons, these being connected by short lengths of tunnel, which are constructed by the shield system. In the wide arm of the Seine there are sunk three caissons, which have a total length of 403 feet. They consist of an iron tube tunnel for double track, which is built up in sections and is then surrounded by a box-like structure. This latter has an iron plating at the bottom and sides, and it can thus be floated in place in order to sink it. Before doing so, the space around the iron tube is filled with cement, so that the structural iron is imbedded in the latter, making a solid mass. The three caissons



SINKING CAISSONS IN THE WIDE ARM OF THE SEINE, AT THE CITÉ



PLACE ST. MICHEL STATION, SHOWING THE ERECTION OF CAISSONS IN THE STREET

are sunk down to the required depth, and are then connected together by means of smaller caissons in order to make a continuous tunnel. The same method is used for sinking the two smaller caissons in the narrow arm of the Seine, which have a combined length of 136 feet. The tunnel tube has a somewhat elliptical shape, with 24 feet width and 18 feet height.

In the Ile de la Cité and Place St. Michel, the underground stations are formed of three caissons each, and these are of considerable size, having

INTERIOR VIEW OF THE MIDDLE CAISSON OF THE PLACE ST. MICHEL STATION

a combined length of near 400 feet for one station. Each of the stations is built on the same principle, that is, using a central caisson which contains the station platforms on either side of the double track. At either end of this structure there is a caisson, which serves to give the passage from the street level to the underground station, and thus contains the staircase and elevator, together with the ticket offices. As to the middle caisson, it is built on about the same interior section as is used is lined with a white tiling which is laid upon a lining of cement. Around the outside of the trusses there is placed an iron plating which covers the whole structure at the sides and ends, and it thus has a rectangular form in the horizontal section. For the station of the Ile de la Cité, the structure is curved around at the top to correspond with the shape of the trusses, but in the Place St. Michel station the vertical section is also made rectangular by the use of structural iron supports

STANDARD TYPE OF STATION OF THE METROPOLITAN LINE

for the regular subway stations. It is made up entirely of iron and cement, and consists of a series of metallic trusses or frames, which have an opening representing the standard section, this being of a general elliptical shape. The trusses are connected by longitudinal iron beams and cross-bracing. Around the inside of the section thus formed is riveted a sheet-iron plating which gives the station section. Within this space are built the two long side platforms with the space for the roadbed in the centre, and the station which are placed vertically at the outside of the trusses. This was done in order to prevent the movement of the ground at the sides while the caisson was being lowered, as the walls of the houses came very near the latter. The inside section of the station is 42 feet width by 30 feet height. On the outside, the caisson measures 54 feet wide and 42 feet high, with a total length of 220 feet. The last-mentioned station is built in a curve of 984 feet radius, and the former one in a 1,970-foot curve. Cement is flowed in between

COMING OUT OF THE METROPOLITAN LINE TO THE OVERHEAD STRUCTURE

the tube portion and the outer part, as in the case of the river caissons. The structure was built on dry ground in an excavation of 3 feet depth, and it was then sunk by the compressed-air method, using a working chamber which had been built in the under part.

The end caisson is a large mass, which has the shape of an immense

GENERAL TYPE OF OVERHEAD STRUCTURE OF PARIS METROPOLITAN

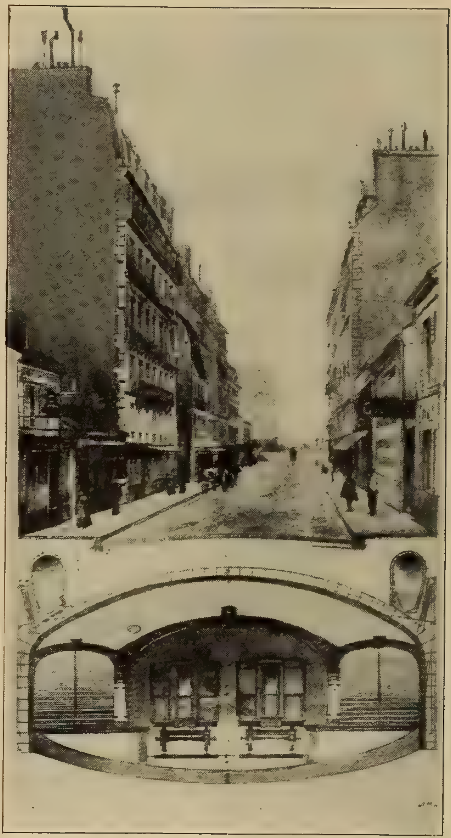
elliptical ring sunk in the ground, having for the lengths of the large and small axes of the ellipse 102 and 83 feet, respectively, while the height of the structure is 78 feet. It is mounted with the large axis lying across the direction of the subway tracks, and is made up of an internal structural iron support, upon which is laid a concentric iron plating on the inside and the outside. The annular space is filled up with cement and there is a top and bottom covering mounted. At each end of the middle caisson there is a similar structure. Each of the caissons is sunk separately, and when in place they are joined together so as to make a continuous station. The size of the whole structure will be seen from the fact that the total length is nearly 400 feet, and it represents a mass of iron and cement weighing nearly 20,000 tons.

At present all the caissons have been sunk, both for the river tunnel and the stations, and the work of finishing this part of the line is being carried out at present. At the same time the rest of the underground tunnel is under way. Half of it is already finished and is now running regularly, this being the northern portion which leads from the Chatelet station, near the Seine, to the northern gate.

Another new section of subway, which is now in progress, has also some interesting work at the point where it crosses the Seine. This line is known as the North-South Subway line, and it is controlled by a separate company from the one which operates the Metropolitan system. It crosses Paris to the west of the last-mentioned line, from the St. Ouen gate on the north to the Versailles gate on the south. As regards the subway in general, it does not show any marked difference from the usual tunnel section, except at the point of crossing the Seine. This takes place at the Place de la Concorde, and for making the passage it was decided to

REINFORCED CONCRETE CONSTRUCTION OVER STATION

use a double metallic tube of 16.5 feet inside section, each tube to contain a single track. The two tubes lie nearly parallel throughout their course, and they are being run under the Seine and the Place de la Concorde in the usual way by the compressed-air shield system.



SUBWAY STATION IN REINFORCED CONCRETE ON THE NORTH-SOUTH LINE

The two tubes branch out from a large underground station on the south bank of the Seine in which is located the air-compressor plant for the time. After crossing the river and running on the north bank, covering a total length of 1,780 feet, the tubes are brought together in a similar underground station, from which starts the double-track tunnel of the regular section. The two tubes lie at distances varying between 23 and 44 feet between centres and they have a partly straight and partly curved path. The work of running the tube is going on at present, it having been started from the south bank.

On the regular double-track tunnel section there has been employed a system of constructing underground stations in reinforced concrete, which has proved quite a success, and we believe it is the first application of this material for subway stations to be made in Europe. It was made necessary from the fact that some of the streets under which the line passes are very narrow, and there is not room between the foundations of the houses for building a station of the regular width. Thus in the Rue de Vaugirard, the available space between the foundation walls was but 48.8 feet, and it was required to build at this point a station which had a 44.6 feet inside opening. This, it will be seen, left only 2.2 feet thickness for the two side walls of the station, but by using reinforced concrete it was found possible to use this thickness. The walls, as well as the vaulted roof, are built of this material, and the roof is strengthened at intervals of 5.3 feet by ribs. The present work was carried out in an open trench in the street, and after the reinforced concrete structure was finished it was given an outside covering of cement over the whole length. Earth was then filled in and the street paving replaced upon it. Another point where a reinforced concrete structure will be necessary is in the Rue d'Amsterdam, where the space is so narrow that the station must be built for half the length with only one side platform, followed by the other half, which contains the second platform.

THE PROBLEM OF THE SMALL REFRIGERATING MACHINE

By Sterling H. Bunnell

MECHANICAL devices of small size and simple design, intended to assist in the task of supplying food, clothing and other necessaries to the family, have become numerous and very efficient. Sewing-machines, cleaning devices and appliances of many kinds for the preparation of food for sale or for consumption, are daily being invented or improved. There remain, however, some fields in which little of practical value has yet been produced.

The development of a practical refrigerating apparatus for the consumer whose requirements do not exceed one thousand pounds of ice per day will fill a want felt by a large number of present purchasers of ice for store or household. It is not that this want is unknown to builders of refrigerating machinery, or that no attempt has been made to supply it; but the operation of a refrigerating machine which is practically a reduced copy of the complete and complicated apparatus of a large brewery or meat storage plant is very far from the automatic process which alone can successfully replace the moderate but even cold-storage temperature of the cake of melting ice. A water-tube boiler and Corliss engine would be quite unsuitable for the man whose wants are properly supplied by a 10 horse-power-gasoline motor. The successful small refrigerating machine must embody the simplicity of the gas engine and sewing-machine in a device that can be installed by an unskilled man and operated under automatic control.

There are already three distinct systems of refrigeration: the compression, in which a gas is expanded after mechanical compression (usually involving liquefaction and subsequent evaporation), abstracting heat from surrounding substances during the expansion; the absorption system, in which ammonia gas, after passing into solution in water, is driven off under pressure by heating the aqua ammonia, liquefied and expanded, abstracting heat from its surroundings, as before; and the vacuum system, in which water is frozen by the effect of a reduction in atmospheric pressure, produced by pumping off the air and water vapour from a closed receptacle by means of a vacuum pump. The first or compression system is operated with any of three or four gases possessing the required features of moderate liquefying temperature and pressure—ammonia, sulphur dioxide, "Pictet fluid" (a mixture of two gases), carbon dioxide, and one or two others. The other two systems are confined to one medium each. There are thus seen to be several forms of refrigerating machines, any of which might serve as the basis of a useful and practical automatic apparatus of small capacity.

The ideal refrigerating apparatus, to do the work now done by a cake or two of natural or artificial ice, must be, first of all, simple and automatic. It will be operated by unskilled hands, usually by labourers, servants or clerks, rarely with the advantage of an occasional moment's attention from a competent mechanic. Self-oiling and self-maintaining mechanism is no impossibility at the present time, so that the compressor and its motive power can be easily produced. The expansion valve, however, offers a difficult problem. A

simple reducing valve will not be sufficient, as the expansion pressure in the refrigerating pipes must vary according to the temperature in the refrigerator, while the maintenance of a constant pressure would allow the refrigerating pipes to fill with liquid whenever the temperature became too low to evaporate the liquid at the set pressure, and thus disarrange the working conditions. Thermostatic control adds a complication which, where simplicity is so necessary, is most objectionable.

With any system the automatic maintenance of proper working conditions presents a serious difficulty. The competent engineer in charge of a large plant has little trouble in maintaining the level of liquid, the strength of liquors, and the pressures in condenser and refrigerator under all conditions which may occur in his presence, by reason of his exact knowledge of causes and effects. Let his night assistant, or some other person less competent than himself, allow the plant to get out of balance, and the chief, hastily summoned to the rescue, may find his ability severely taxed. A plant, though of small size, involving all the details of a standard large apparatus, will evidently be quite beyond the abilities of ordinary unskilled help. Leakage through joints and stuffing boxes is one principal cause of disarrangement. The loss of a small quantity of fluid will reduce the condenser pressure below the so-called "critical pressure," stop the liquefaction of the fluid, and reduce the refrigerating effect to a small fraction of the proper amount. With all gases but carbon dioxide leakage is greatly feared, from the danger to stored goods and even to the lives of the attendants by the pressure of free ammonia, sulphur dioxide, ether, or other poisonous or odorous gas. The use of safety-valves is, therefore, impossible, so that there is no protection against excessive pressure caused by careless operation of the apparatus.

From the points of view of buyer and seller alike, first cost of apparatus must be kept down. Refrigerating salesmen are generally engineers as well, able to plan all parts of the piping system of usual plants for brewery or cold storage, estimate the cost and draw up the specifications and guarantee of performance. The apparatus is set up by an erecting foreman, who is able to hire necessary help, superintend mechanical work and pipe fitting, and put the plant into successful operation while training the regular force which is to take charge later. The construction of small plants by these methods is impossible, by reason of the excessive expense involved by the services of such expert men. It costs little more to plan and sell the machinery for a hundred-ton plant than to do the same for a little, two-ton outfit covering several small refrigerators, say in a restaurant. In order to sell at a price attractive to the average user of ice in small quantities, the small plant must in some way be standardized, so that it may be constructed in lots all alike, sold by agents of the ability of those who sell sewing-machines or farm implements to the consumer direct, and shipped from stock upon order, to be set up by the user under direction, or by a mechanic of ordinary ability. Such a plant will be salable for a moderate percentage over its cost, and in quantities which will make it possible to build up a business of large proportions.

The principal requirements may be summarized in the three terms—simplicity, self-regulation and standardization. With the successful meeting of these requirements, a practically useful device will be produced. A fourth condition—economy—is relative only. A device satisfying the three indispensable needs will be useful at least for wealthy residents in warm countries, and will have some possible scope of sales. Similarly reasoning, no degree of economy could make an artificial refrigerator useful in the Far North, where ice

and low temperatures are only too easily had. For simply replacing ice-produced temperatures by mechanical refrigeration, the machine must cost less to operate than the cost of supplying ice. Other conditions may extend the field of the machine, as the uncertainty of a regular supply of ice from natural sources or at reasonable prices, or the desirability of temperatures near to or lower than 32 degrees Fahrenheit, as for preservation of meats and fish over long periods. The cost of mechanical refrigeration depends on well-established data and conditions, which limit the possible economy in any special case. The small machine will be subject to the same limitations, and its performance will necessarily fall short of the efficiency of the larger apparatus. Its field of usefulness will obviously be extended by its operation at the maximum possible efficiency.

The designer who attempts to step boldly forward from the class of small plants offered to-day, mostly by the builders of large plants to fill up their unused capacity during dull periods by occasional desultory sales of reduced copies of their standard refrigerating apparatus, must make up his mind to deal with the problem as a new and different one, with its own special requirements to be met and satisfied. Between possible systems the choice is principally in the pressure required. Refrigeration by direct evaporation of water demands the lowest pressure, a mere fraction of an atmosphere, an inch or so of mercury above absolute vacuum. In order, there follow ether, sulphur dioxide, the Pictet mixture of the dioxides of sulphur and carbon, anhydrous ammonia and carbon dioxide, being all the gases obtainable at moderate cost and liquefiable at pressures obtainable by simple compressors. The horse-power required per ton of refrigeration per twenty-four hours, disregarding mechanical losses, is practically the same for all refrigerating mediums. The cylinder capacity of the compressor must, therefore, vary inversely with the pressure required.

The mechanical efficiency of the large cylinders required with the low pressure of the water-vapour system or the 12 (by gauge) pounds necessary for ether will be low compared with the cylinders of moderate dimensions compressing sulphur dioxide or Pitcet fluid to 60 pounds. Ammonia at 180 pounds affords very satisfactory operating conditions in large plants, but is objectionable by reason of its strong odour and deadly effect in case of leakage; while carbon dioxide, inert and odourless, and therefore safe, requires pressures from 1,000 to 1,300 pounds per square inch, which may not be objectionable for large plants, but cannot be considered ideally suited to the small outfit for use in unskilled hands. Of these four principal refrigerants, sulphur dioxide or Pictet mixture seems most suitable.

The ammonia absorption system, while unique in requiring no energy but the heat of exhaust steam and enough power to operate a small circulating pump, will not make a satisfactory small plant, because of the degree of skill required to operate it, maintaining the strength of the solutions and the levels in the retort and absorber. There is no way apparent to make the regulation automatic.

The compressor of the system will be designed for capacity on usual lines, but should be as self-lubricating and frictionless as the present-day automobile engine. This model will settle all questions of the best designs for wearing parts and valves. The stuffing-box for the piston-rod is the most important and perplexing detail of the entire apparatus. Stationary joints of pipe, condenser and receiver can be made tight or done away with; but the sliding joint of the piston-rod affords an escape for refrigerating gas, dissolved in the film of oil, if not actually blowing through. If leakage cannot be prevented absolutely, the gas lost must be replaced from time to time, and

some means of measuring the quantity lost and replaced must be arranged. Internal lubrication for the compressor cylinder should be omitted; by running with oil until a glaze is formed on the cylinder walls, it ought to be possible to run dry and prevent filling the pipes with oil and eventually clogging up the system.

There is a French refrigerating machine, made in small sizes only, which actually operates without a stuffing-box, so that the system is hermetically sealed. This is at the sacrifice of accessibility, and the design cannot be used for more than one ton daily capacity. The means of preventing stuffing-box leakage is the designer's hardest problem. Outside of this, the pipe system need have no joints that can possibly leak. Simplicity and cheapness require a compact condenser and expansion coil, made with welded or soldered joints only. If the capacity of the condenser is made large enough to contain the entire charge of refrigerating fluid, the plant will be safe against explosion. The expansion coil should be in a brine-cooling tank; direct expansion would prevent the complete erection of the plant in the builder's shop, while brine-circulating pipe can be put up by any pipe-fitter or plumber and extended in future, if desired. The proposed line of small refrigerating machines should consist of two or more standard sizes of compressor, condenser and brine cooler, each self-contained and compact, and with connections involving but three separable joints, and these to be sweated after erection. The purchaser will provide his own brine-circulating pipe and put it up.

As to the operation of the small plant, the expansion valve may, perhaps, be best managed by having none at all—just an orifice through which a constant quantity of liquid may pass. On starting the plant after a stop, the liquid will be found in the brine-cooler pipes. The compressor will draw off the vapour, raise the pressure in the condenser and cause liquefaction, while the temperature of the expansion pipes and the surrounding brine will steadily fall. In time, if the machine is not too small for the work required, the temperature will fall so that the liquid will evaporate but slowly, and the compressor will receive but a scanty supply of vapour. The condenser pressure will then fall accordingly, and the flow of liquid through the orifice will decrease, and this will check the fall of temperature in the expansion coils. Theoretically, with a fixed orifice for the liquid passing to the expansion coils, the speed of the compressor could be increased to produce lower temperatures or decreased to produce less degrees of cold.

By manufacturing but three or four sizes of standard apparatus, the machines could be sold from catalogues, and their performance measured in gallons of brine cooled a specified number of degrees. The manufacturer would thus sell against a positive guarantee, and would be spared the uncertainty and expense of undertaking to refrigerate a lot of miscellaneous boxes with doors frequently opened and infrequently closed tight; while the purchaser would know that he was getting refrigeration equal to a specified weight of ice, and that the manner in which that refrigeration was used was his own affair. Between the expense of designing and selling special coils and connections and the cost of erecting and testing to the satisfaction of the purchaser in a busy meat market, restaurant or provision store, doing work out of business hours and risking an expensive stock while adjusting the plant for regular operation, the margin of profit from the small refrigerating apparatus as at present constructed is near or past the vanishing point. By delivering from stock a standard apparatus of demonstrable capacity and efficiency, the cost will be known in advance, and the selling price can be arranged accordingly.

MOTOR PASSENGER-VEHICLES

By J. F. Gairns

THAT the application of mechanical power for public-service passenger vehicles, such as omnibuses, sight-seeing cars and the like, should be an important section of the motor vehicle industry is inevitable, and, although ordinary motor cars and commercial load-carrying motor vehicles are still by far the most numerous, the number of motor-omnibuses or like vehicles in use in Great Britain, as well as in other parts of the world, is now very large, so that, following on previous articles dealing with "Industrial Motor Vehicles" and "Road Tractors," contributed to these pages by the present writer, a systematic and fairly exhaustive review of this section of industry will be in place.

The motor-omnibus or sight-seeing car depends upon its patronage for a multiplicity of small or comparatively small fares, and for that reason its carrying capacity must be considerable. Usually a double-decker omnibus will seat at least forty passengers, and most other vehicles, unless of very small size, will accommodate about twenty or twenty-five passengers, if not more. Consequently the weight to be dealt with is considerable. The service must be regular, reliable and substantially free from breakdowns, if it is to maintain a good character and attract patronage. The strain of continually stopping, starting and checking on crowded routes is a serious factor; so that a high degree of efficiency is called for, notwithstanding that the fares are necessarily usually low and the margin between profit and loss a very fine one.

The various duties for which the motor-omnibus or corresponding passenger-conveying public-service vehicle may be used can be briefly reviewed as follows:

(1) Small omnibuses for station or hotel service. As a rule, these are used for what may be termed "private" service, as for conveying hotel visitors between railway station and hotel, as they do not convey sufficient traffic to pay their way if dependent wholly upon omnibus fares.

(2) Single - decked omnibuses. Probably, in most cases where single-decked omnibuses are used in Great Britain, it is because the traffic to be dealt with is comparatively small, but abroad the single-decked omnibus is by far the most usual. And in many cases these single-decked vehicles are of considerable size and have good seating capacity in proportion to size; but they are most frequently employed for routes of smaller traffic in Great Britain. In some cases they have a luggage compartment, and there are instances of the division of car omnibus body into compartments for different classes of passengers.

(3) Small double - decker omnibuses. As a rule, the carrying capacity of a small double-decker omnibus is greater than that of a considerably larger single-decker, though where luggage has to be conveyed in quantity, the single-decker vehicle is preferable, as the luggage can then be placed on top. These small vehicles are usually used on routes of small traffic, sufficient only to justify a vehicle of medium size, or, as is often the case, on routes where the gradients are so heavy that it is necessary to limit the passenger ca-

pacity, though the chassis and power provided may be similar to those used for much larger vehicles.

(4) Large double - decker omnibuses. These are most extensively used, particularly in large towns and in competition with tramway services, but it is in London that the large double-decker motor-omnibus is seen at its best. This is mainly due to the fact that London stands almost alone in depending for its about-town transport in the central districts very largely upon the omnibuses, and in other districts the competition between them and the various electric tramways is very keen, because the omnibuses, though following, in many cases, the same routes as the tramcars, also traverse the central business districts and cater for through traffic as well as what can be obtained in actual competition with the tramways. Motor-omnibuses are also employed in many cases in connecting outlying districts, or for cross journeys that are not catered for by tramways or railways; and they are used by many railways for acting as feeders to the railway trains, running over selected routes to and from a railway station. As regards financial conditions it would appear that it is in these other duties that the motor-omnibus can really be operated as a paying concern, for the competition on the principal routes of travel through central London, for example, and the direct competition on tramway routes is not conducive to dividend-earning, judging from the reports of the great omnibus companies of London.

FIG. 1.—A CLARKSON STEAM MOTOR-OMNIBUS

Besides the motor-omnibus there are a number of vehicles of passenger-carrying class which will be dealt with in this article, and they may be reviewed as follows:

(5) Sight-seeing cars. Considered as an open-air omnibus, these vehicles are largely used in the summer and on holiday routes for work of an omnibus character, but it is a vehicle for running pleasure trips to places of interest in the neighbourhood of holiday resorts that they are principally employed. The arrangement of banked-up seats is very suitable for sight-seeing, but is, of course, unsuitable for omnibus work where pas-

sengers are frequently taken up or set down.

(6) Pullman omnibuses. Some of these are in use in London at higher fares than the usual omnibus, but the difference is mainly one of the equipment with movable arm chairs and the like of the interior of a single-decker omnibus. Corresponding small omnibuses are sometimes used as traveling dressing rooms for theatrical artists and the like. Various types of omnibuses have also been adopted for advertising service, and in some cases mechanism is fitted whereby advertisements are changed as a vehicle progresses.

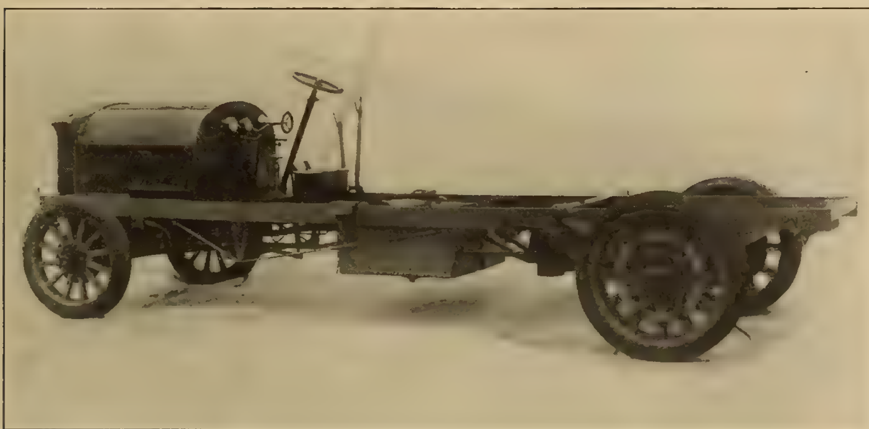


FIG. 2.—MODIFIED CLARKSON STEAM CHASSIS

(7) Motor fire tenders and fire-escapes. A number of these are in use, but so far they are still somewhat exceptional, though this is not likely to continue for long, as many firms are entering the field with various designs of such vehicles adapted for the special requirements of fire service.

(8) Motor fire engines. The application of the internal combustion engine in place of steam is practically inevitable in fire-engine development, in view of the developments that have occurred to the motor vehicle industry, though progress has been slow because the possibility of breakdown on a journey to the scene of a fire is a serious matter. Consequently, the motor fire engine has only appeared in small numbers until lately, but it appears probable that a considerable number of them will shortly be in use, owing to the fact that the internal combustion engine is now sufficiently reliable to justify its employment for fire engines. In this application there is one strong argument in favor of the internal combustion engine in that the engine is used both for propelling and for pumping, whereas on a steam fire engine the boiler is raising steam for pumping on its journey to the scene of operations while hauled by horses. Moreover, there is no delay in getting to work, there is no boiler to be looked after and maintained, ready for steam-raising while not actually in use, and the space occupied by the engine, pump and other equipment is very small. Also, owing to the economy of space and weight, a fire engine can convey a number of firemen on itself, instead of a separate fire tender being required.

Although steam still occupies an important place in the commercial motor-vehicle industry there are comparatively few instances of its use for motor-omnibus, sight-seeing cars and like vehicles, while it would appear that even this use will diminish, al-

though there is no reason to consider that the steam systems in use are inefficient; rather it is that the petrol-propelled vehicle is generally more suitable, convenient, lighter, occupies less space and requires less attention. Therefore it follows that a majority of the examples of practice to be described relate to the petrol vehicle. In addition, however, reference will have to be made to the small field of electric-propelled vehicles, and the experimental employment of petrol-electric systems. Consequently a selection of representative vehicles of those classes which come within the purview of this article will be described in the order indicated, viz., (1) steam propelled, (2) petrol propelled, (3) petrol-electric systems, (4) electric vehicles.

The fields of gas propulsion and the use of suction-gas apparatus are too experimental to require consideration, though mention thereof is necessary for completeness.

A—STEAM OMNIBUSES, ETC.

Although most of the makers of heavy steam wagons and lorries have at one time or other constructed a few omnibuses and like vehicles by fitting a suitable body to a standard steam chassis, most of these date back some two or three years or more; but most of these have been somewhat spasmodic, and, as a rule, practice has given way to the petrol-operated vehicle. But one firm, which was a pioneer in the adaptation of mechanical power for road transportation, has consistently adhered to steam for all classes of vehicles, and to-day nearly all of the steam-propelled vehicles used in London (not a very large number, but still fairly large) are Clarkson omnibuses, and a number of such vehicles are in use elsewhere.

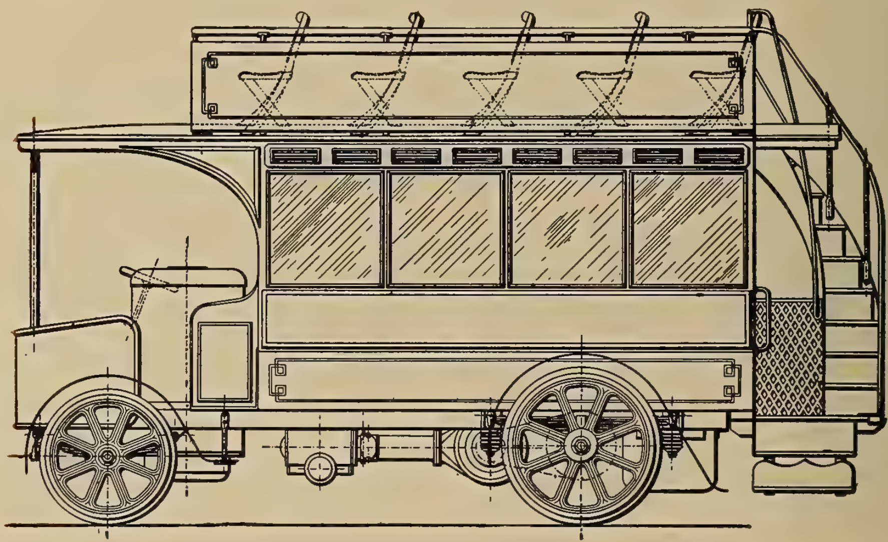


FIG. 3.—DESIGN FOR STEAM OMNIBUS. ALLEY & MACLELLAN, LTD.

Fig. 1 illustrates a modern steam omnibus, constructed by the firm of Clarkson's Ltd., of Chelmsford. As will be seen, the driving platform being raised, affords the principal means of identifying these vehicles, as they present a very similar appearance to petrol omnibuses in other respects. In some cases the driving platform is located even higher than in the example illustrated, and most of the vehicles used in London are of that class. In the earlier days this firm adopted a vertical boiler, but it is almost prohibitive to use any ordinary type of boiler for double-

decker omnibuses, owing to the fact that the gases from the chimney escape near to the passengers on top (most of the vehicles thus constructed were therefore single-deckers); consequently in all the more recent examples a water-tube generator, with thermostat and pressure control for oil fuel and water, is employed. The engine, of two-cylinder, compound reversing type, is located near the body, and drives by side chains; no change speed-gearing being necessary. The working steam pressure is 300 pounds per square inch.

FIG. 4.—TWO SINGLE-DECKER OMNIBUSES FOR THE LONDON & SOUTH WESTERN RAILWAY. J. I. THORNYCROFT & CO., LTD.

Recently an interesting adaptation of the Clarkson system to a petrol chassis was carried out by this firm, Fig. 2 illustrating the chassis as thus converted. The object was to produce a steam chassis of the same type as the usual petrol chassis, but little of the original chassis was retained, though the ensemble, when complete, is very similar in general style. This was, however, carried out as an experiment, and in future cases the design will be adopted for new construction with greater ease. The weight of the chassis as modified is considerably less than the usual Clarkson chassis. The engine and differential gear take the place of the old differential gear box, and drives the rear wheels by the existing transmission mechanism. The water-tube boiler, working at 300 pounds per square inch, and the condenser with the ventilating fan are placed under a bonnet in front, and the fuel and water tanks are located under the frame about midway. Two pumps are operated by the engine, one for oil and the other for water, and automatic thermostatic and pressure control are provided. A foot pedal is provided whereby the engine only remains in operation while this is pressed down, and the valve gear and other control mechanisms are placed conveniently for the driver.

Judging from results obtained with this chassis in use, its operation is very satisfactory, and all the Clarkson vehicles are now working very well, though we understand that in the earlier stages of development a good many difficulties were experienced, which fact possibly goes to

FIG. 5.—DOUBLE-DECKER OMNIBUS FOR CAMBRIDGE SERVICE. THE NEW ARROL-JOHNSTON CAR CO., LTD., UNDERWOOD, PAISLEY

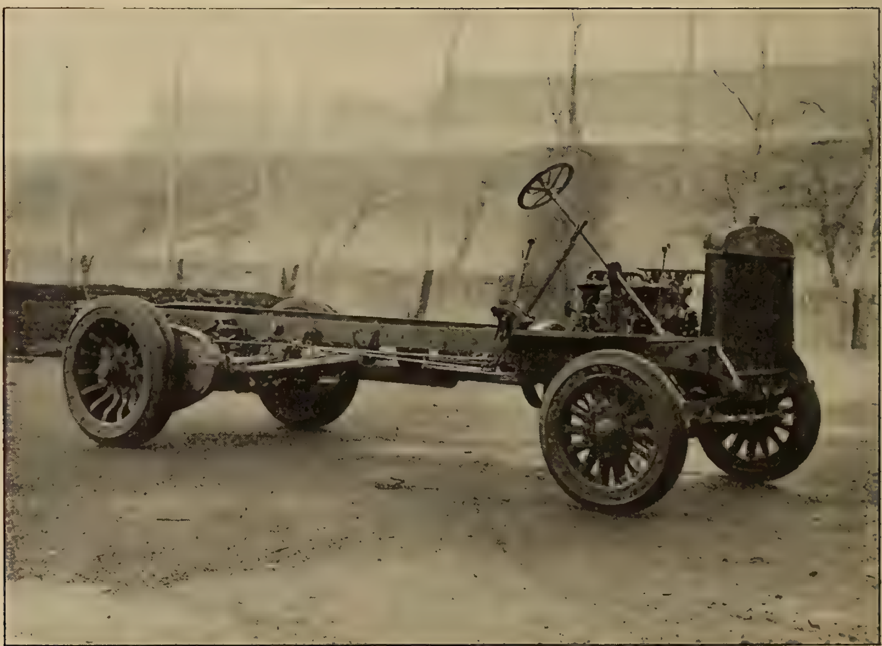


FIG. 6.—CHASSIS AS SUPPLIED FOR LONDON SERVICE TO THE CAMBRIDGE MOTOR OMNIBUS CO., LTD.

explain why the Clarkson vehicles are not yet in greater use, though their number is still fairly large.

A few steam vehicles have been constructed by Sidney Straker & Squire, Ltd., and one of these, though we are not able to illustrate it, is worthy of remark. It is a double-decker with roof canopy and front glass screen on top, so that roof passengers are not inconvenienced by fumes from the chimney. In this case the boiler is of ordinary vertical type.

At present roof canopies for double-decker omnibuses are almost unknown, but there is a tendency to introduce them, in the same way as covered-in double-decker tramcars are becoming very common, and in that case it would be easy to employ a chimney, as in the case of steam wagons and single-decker omnibuses, so that extensions of the use of steam for omnibuses may be expected, though the general favour of the petrol omnibus will probably prevent very great developments in this connection. Steam will always present the advantage that almost the whole control can be effected at the engine, whereas a petrol vehicle requires speed gears and a clutch, besides being more complicated.

Although the firm of Alley & MacLellan, Ltd., of Glasgow, is not yet on the market with a steam omnibus, designs have been prepared therefor, and Fig. 3 illustrates the general features in line drawing. The chassis corresponds practically with the standard steam chassis for wagons and lorries as constructed by this firm.

FIG. 7.—DOUBLE-DECKER OMNIBUS. CRITCHLEY-NORRIS MOTOR CO.

It will, therefore, be sufficient to mention that the boiler is of vertical tubular design, while the engine is a two-cylinder non-compound, with a cam valve gear providing for variable cut-off and reversing.

The Critchley-Norris steam chassis, previously described, has now been adopted for omnibus work, this design presenting the appearance of a petrol chassis, and having points in common with the modified Clarkson chassis for wagons and lorries have also been adapted to a slight extent, as previously mentioned.

PETROL OMNIBUSES.

In view of the fact that the large majority of motor-omnibuses are petrol-operated, and there is a good deal in common with the chassis employed for motor wagons and lorries, many of which have been described in engineering detail in previous issues of this magazine, so that it will be sufficient to refer to some of the examples to be illustrated somewhat briefly.

Fig. 4 illustrates two neat single-decker vehicles recently constructed by Messrs. J. I. Thornycroft & Co., Ltd., for the London & South Western Railway. As feeders for the railways motor omnibuses of this type and of the double-decker types are fairly extensively used by several railways. The Great Western Railway, for example, has about fifty of these services, with very satisfactory results.

Fig. 5 illustrates a petrol omnibus of the double-decker class recently supplied by the New Arrol-Johnston Car Co., Ltd., of Paisley, for the Cambridge Motor Omnibus Co., Ltd., and Fig. 6 illustrates a larger chassis as supplied for full-sized vehicles in London service.

Fig. 7 illustrates a neat omnibus as constructed by the Critchley-Norris Motor Co., of Bamber Bridge, and providing seating accommodation for 34 passengers.

Fig. 8 illustrates a large omnibus supplied to the Great Eastern Motor Omnibus Co., Ltd., for London service, by Sidney Straker & Squire, Ltd.

Fig. 9 illustrates a large motor omnibus constructed by J. & E. Hall, Ltd., of Dartford, Kent ("Hallford" vehicles).

FIG. 8.—MOTOR OMNIBUS. SIDNEY STRAKER & SQUIRE, LTD.

Fig. 10 illustrates a single-decker omnibus by the Ryknield Motor Co., Ltd., of Burton-on-Trent.

Another firm largely concerned with the manufacture of motor-omnibuses, many of them being extensively engaged in the heaviest London traffic, is Dennis Bros., of Guildford, and Fig. 11 illustrates their standard heavy omnibus chassis.

In addition to those specifically mentioned it will, of course, be understood that many other firms could now be mentioned, but the examples

FIG. 9.—LARGE OMNIBUS MADE BY J. & E. HALL, LTD.

illustrated are sufficiently indicative of practice.

B—MOTOR SIGHT-SEEING CARS.

For pleasure and sight-seeing trips this type of car is by far the best medium, and for that reason these vehicles are extensively employed between holiday centres and places of local interest, in place of the horse-drawn wagonettes and like vehicles previously used, and a few of these will now be referred to, though the main features are apparent from the illustrations, and the characteristics of the engine and mechanism have been already set forth in dealing with the commercial vehicle practice of the same firms.

Fig. 12 illustrates a neat sight-seeing car constructed by John I. Thornycroft & Co., Ltd.

Fig. 13 illustrates an 18-seated sight-seeing car constructed by Argyll's, Ltd., of Glasgow.

Fig. 14 illustrates a 25-seated

FIG. 10.—SINGLE-DECKER OMNIBUS RYKNIELD MOTOR CO., LTD.

sight-seeing car constructed by the New Arrol-Johnston Car Co., Ltd., as supplied to the North British Railway Co., and Fig. 15 illustrates another vehicle of the same firm fitted with canopy and windscreen.

Fig. 16 illustrates a large sight-seeing car constructed by Messrs. Durham, Churchill & Co., Ltd., of Sheffield.

Fig. 17 illustrates an unusual type of sight-seeing car as supplied for service in Cairo by Sidney Straker & Squire, Ltd.

A few variations of the usual type of motor sight-seeing car have also been introduced, and one of these may be mentioned, though we are not able to illustrate it. It was supplied by Dennis Bros., of Guildford, for service in Rio de Janeiro, and besides the usual sight-seeing car body, with seats on a level, and with canopy, it has a roof with omnibus seats.

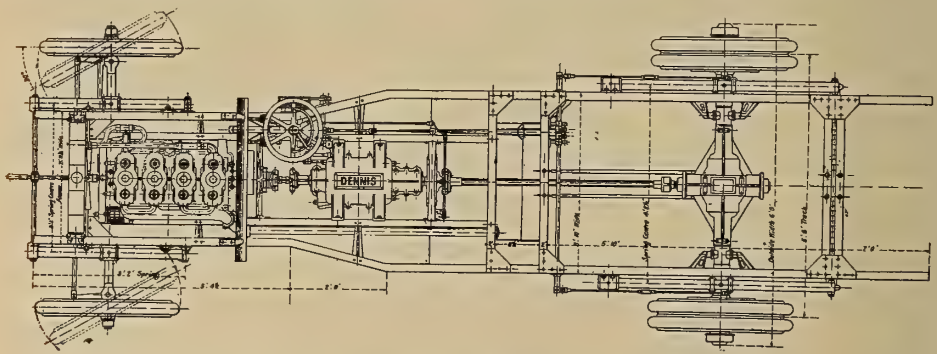


FIG. 11.—PLAN OF THE DENNIS 35-HORSEPOWER, 3-TON OMNIBUS CHASSIS

C—PETROL ELECTRIC VEHICLES.

Although these vehicles are still only in the experimental stage, they are sufficiently interesting for more detailed consideration, and their potentialities are considerable, owing to the fact that there is a good deal to be said for the double-transmission method of operation, though a few years ago such designs would have been considered freakish.

In these designs the petrol engine is unaffected by the strains of direct propulsion. It runs at a practically constant rate and with a constant output, and although it operates a dynamo which supplies current for the propelling motors, the favourable conditions under which the engine works and the absence of gears and gear transmission more than compensates for any losses due to the double conversion.

Fig. 18 illustrates a petrol-electric omnibus chassis constructed by the firm of Sidney Straker & Squire, Ltd., and fitted with electric equipment by the British Thomson-Houston Co., Ltd., the vehicle being at present under trial in the London district.

The system consists briefly of a dynamo driven by a petrol engine, the whole of the engine power being converted by the dynamo into electrical energy, which is transmitted through a controller to two motors driving the road wheels. The dynamo is coupled direct to the engine, the armature acting as a flywheel. In order to ensure rigid alignment the dynamo frame is bolted to an extension of the engine crank chamber case, the whole forming a compact unit. Two motors are provided, each driving a road wheel independently, no differential gear being required. They are arranged to be suspended one on either side of the chassis. Each motor is supported from the main frame, and the motor shaft of each carries a hardened steel worm meshing with a worm

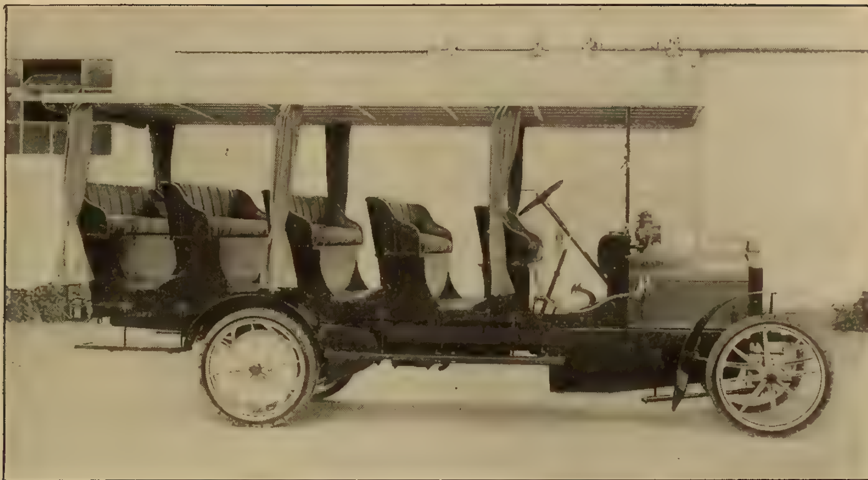


FIG. 12.—SIGHT-SEEING CAR. JOHN I. THORNYCROFT & CO., LTD.

wheel mounted on the inside end of a second-motion shaft. To the outside end of this shaft is fixed a chain pinion, driving the road wheel by means of a silent chain. There are thus two second-motion shafts, each driving one road wheel, and eliminating the necessity for differential gear. The second-motion shafts, together with the worm and wheel gears, run in oil-tight cast steel casings, and are mounted on ball bearings throughout. If necessary, the motors can be quickly dismounted.

The petrol motor is of the four-cylinder type, developing 32 brake horsepower at 900 revolutions. It is controlled by a centrifugal governor designed to cut out at 450 revolutions when running light, and acting directly upon the throttle valve.

The dynamo is of the B. T. H. automatic regulating type, designed to maintain a constant load at a constant speed on the engine, ir-

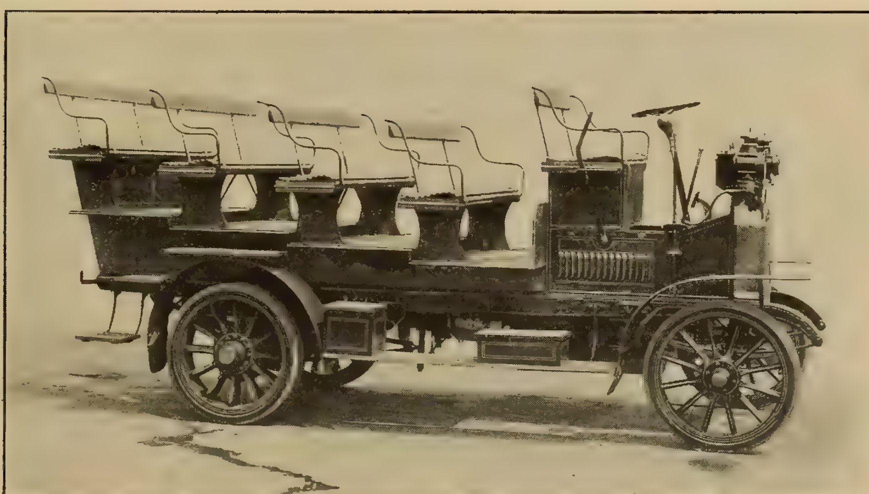


FIG. 13.—ARGYLL EIGHTEEN-SEATED SIGHT-SEEING CAR

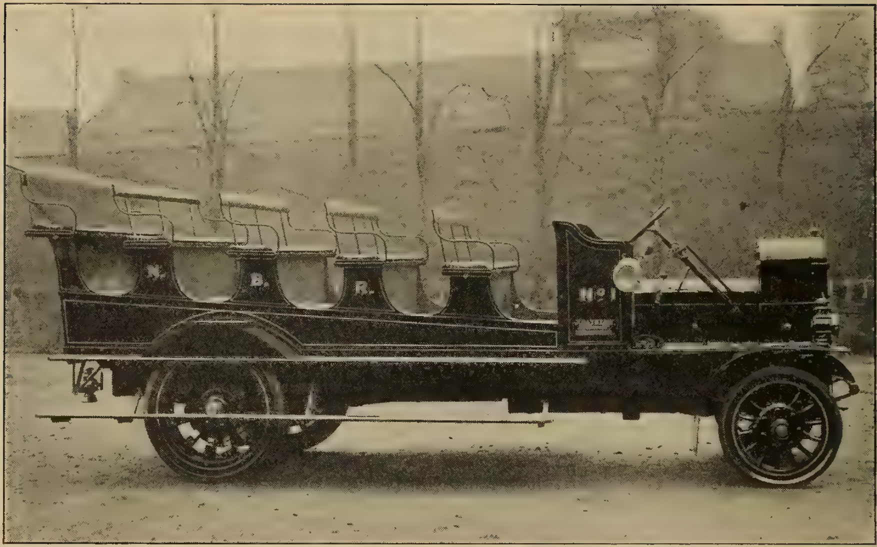


FIG. 14.—SIGHT-SEEING CAR SEATING TWENTY-FIVE PERSONS, AS SUPPLIED TO NORTH BRISTOL RAILWAY CO. THE NEW ARROL-JOHNSTON CAR CO., LTD.

respective of the varying load demands of the vehicle. In other words, the product of volts and amperes output is at all times a constant, for as the ampere load demand increases, as, for example, when the vehicle is climbing a grade, the volts correspondingly decrease in such a manner that the load, and, therefore, speed of the engine, remains unaltered. This is brought about entirely automatically by a suitable arrangement and design of the dynamo windings, and without the use of moving contacts. The dynamo is rated 15 k.w. 130/65 volts,

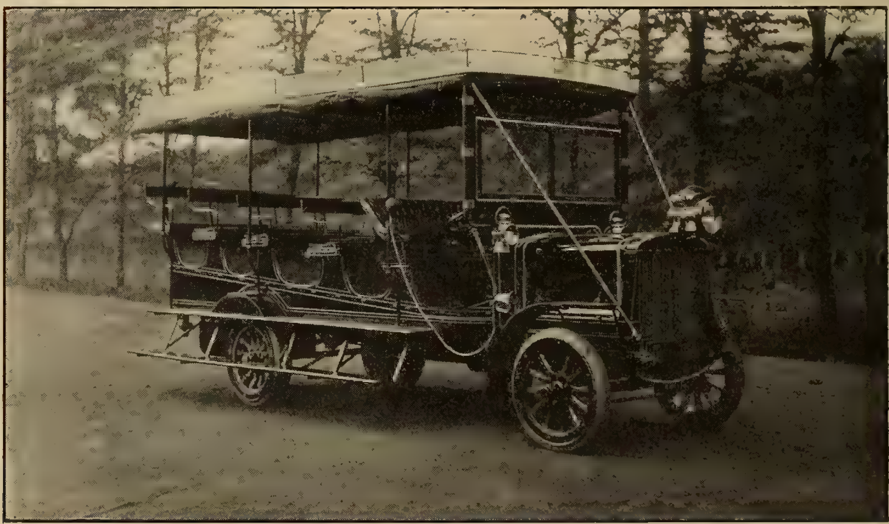


FIG. 15.—SIGHT-SEEING CAR FITTED WITH CANOPY AND WIND SCREEN. THE NEW ARROL-JOHNSTON CAR CO., LTD.

850 revolutions per minute. It is enclosed with removable aluminum covers, which completely protect it from dirt and water, etc.

Each motor is rated 7½ k.w. constant input 130/65 volts, 1400/500 revolutions per minute. They are series wound, and are totally enclosed with removable aluminum covers, which completely protect the windings from water when the vehicle is washed down.

The system of control is extremely simple. To the right of the driver in the position usually occupied by the change speed lever is mounted the "operating box" containing the control lever, which is coupled by means of an endless chain to operate the controller proper. The latter is located in a convenient position close to the motors and generator, thus reducing the length of the necessary cables to a minimum. The controller provides the following motor connections: first speed forward, motors in series; second speed forward, motors in parallel; an "off" position; reverse, motors in series.

In the "operating box" is also mounted a small resistance, and control switch in circuit with the generator field. A foot pedal is arranged to be coupled to the engine governor, and to this field control switch in such a manner that when the pedal is fully depressed the engine is governed to run at 450 revolutions per minute, and at the same time the switch is moved to insert a resistance in the generator field sufficient to reduce the main volts to practically zero. No current flows to the motors, and the vehicle is stopped. On releasing the pedal the first movement cuts the resistance out of the generator field, causing sufficient current to flow to the motors to start the vehicle, which will continue to run slowly, the engine remaining governed at 450 revolutions per hour. On entirely releasing the pedal, the governor is "held up," allowing the engine speed to at once increase to its normal 900 revolutions per minute, and the vehicle will accelerate to its full speed. The engine speed is prevented from exceeding 900 revolutions per minute by the restraining influence of the gen-

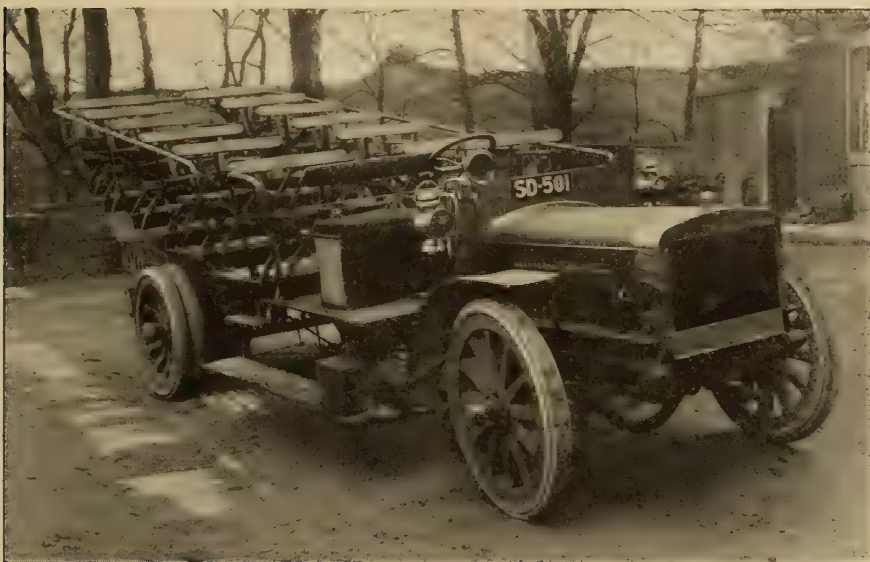


FIG. 16.—SIGHT-SEEING CAR. DURHAM, CHURCHILL & CO., LTD., SHEFFIELD

erator, and the increased torque required at starting, or on climbing grades, has no influence in reducing this speed, owing to the automatic constant load demand of the generator, which ensures the engine speed remaining unaffected whatever torque may be required at the road wheels. The engine, therefore, runs at its normal speed, and develops its full normal horsepower during the whole of the accelerating period. The rate of acceleration is limited solely by the size of the engine and not by the skill of the driver. Once the pedal is released, the acceleration is entirely automatic, and the maximum available power is delivered to the road wheels without any loss due to slipping of clutch or reduced engine speed.

The vehicle is started on the top speed, i. e., motors in parallel, and the main circuit is not broken in stopping and starting, and, therefore, no sparking occurs at the controller contacts. The controller is only operated for reversing, and in climbing grades exceeding 1 in 20, when better results may be obtained by running on the first forward series position, but on the other hand no damage can occur to the equipment if the driver neglects to change the speed.

In cases where it is necessary to travel for long distances at reduced speeds, it is not convenient to regulate by the foot pedal, but for this purpose a hand lever is provided, which independently controls the engine speed and allows the pedal to be released.

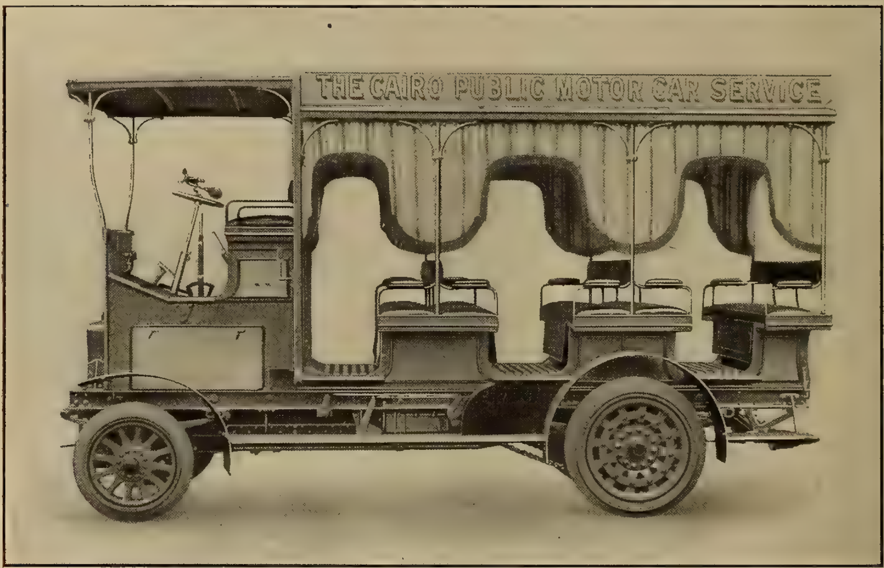


FIG. 17.—FAR-EAST MODEL SIGHT-SEEING CAR. SIDNEY STRAKER & SQUIRE, LTD.

Under certain circumstances, as, for example, when climbing grades, it is desirable to accelerate the engine speed for short periods in order to obtain the maximum power available. This is provided for by coupling the hand lever to the field switch in correct sequence, and in such a manner that after the hand lever has been moved to a position corresponding to nominal engine speed of 900 revolutions per minute a further movement inserts a portion of the field resistance, which alters the load demand of the generator and permits the engine to increase in speed and deliver to the generator its max-

imum available horsepower. By this means full advantage can be taken of the additional horsepower that may be obtained by running a petrol engine for short periods above normal speed.

From the foregoing it will be seen that the control is extremely simple and requires no skill on the part of the driver. The vehicle is stopped and started by a foot pedal which can be worked with any degree of suddenness without causing shock at starting or damage to the engine or transmission. The speed is controlled in traffic by the same pedal, or for long distances by a hand lever, by which the engine speed can also be accelerated at will. Under running conditions the hill that would necessitate a change in a mechanical gear, is negotiated by the electric transmission at the maximum speed for each particular grade, without any action on the part of the driver, the automatic generator supplying the motors with the necessary current to enable them to develop the torque required, while at the same time the engine load, and therefore its speed, is also automatically kept constant. Owing to the extremely smooth starting and uniform acceleration the wear on the tires will be considerably reduced.

FIG. 18.—PETROL-ELECTRIC OMNIBUS CHASSIS. SIDNEY STRAKER & SQUIRE, LTD.

Fig. 19 illustrates a petrol-electric omnibus constructed by J. & E. Hall, Ltd., of Dartford, Kent. In this design, also, the propelling motors are arranged one on each side of the frame, but they act directly upon the rear wheels by worm gearing. The general characteristics of the equipment are necessarily very similar to those of the system previously described.

D—ELECTRIC SYSTEM.

Although there is a good deal to be said as regards the undoubted desirability of a satisfactory method of applying electric power to

FIG. 19.—PETROL-ELECTRIC OMNIBUS. J. E. HALL, LTD.

omnibuses and like vehicles, the disadvantages have so far been sufficiently serious to prevent extensive employment, though in the United States such vehicles are fairly largely used. These disadvantages relate principally to (1) the necessarily heavy weight of even the most efficient accumulators for large powers to operate over an extended radius; (2) the necessity for charging equipment at one or more power stations

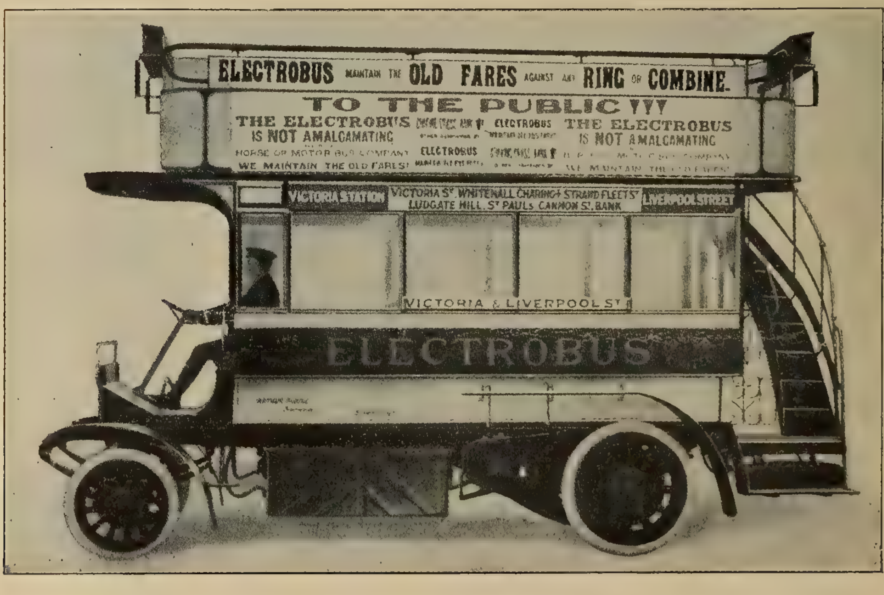


FIG. 20.—ELECTRIC OMNIBUS. THE LONDON ELECTROBUS COMPANY, LTD.

to which the vehicles must repair for recharging, and (3) the comparatively limited area over which such vehicles must work, and the difficulty of sending them on longer or unusual journeys, or on special routes which may take them dangerously far away from a charging station.

Notwithstanding these disadvantages, which are becoming less and less serious as the industry progresses, there is one important company operating electric omnibuses in the London district, and Fig. 20 illustrates one of their vehicles. The vehicles of the London Electrobus Co., Ltd., are provided with two propelling electric motors, with control gear conveniently arranged for the driver, and a large battery box arranged under the frame. The equipment is therefore very simple, and all the advantages of electric power, with its cleanliness, simplicity of control, absence of change-speed gear lever and the like, quietness of operation, are realized thereby.

At the charging station of the company in Westminster entering vehicles proceed up a slight vamp over a movable traverser, and when in position with its wheels spanning the traverser, a hydraulic lift raises an empty traverser until it supports the battery box of the vehicle, the cables are disconnected and the battery box can then be unfastened and lowered by the lift until the traverser with its load can be run out of the way. A charged battery box is then run into position, raised and connected up to the vehicle, which is then ready to be run out for another journey.

The usual journeys of these vehicles are about 10 miles between recharging, in the midst of heavy traffic requiring frequent starting and stopping, but this does not represent the maximum possible.

The foregoing describes the only application of electric power on a large scale for motor omnibuses and like vehicles, but there have been several experiments in connection

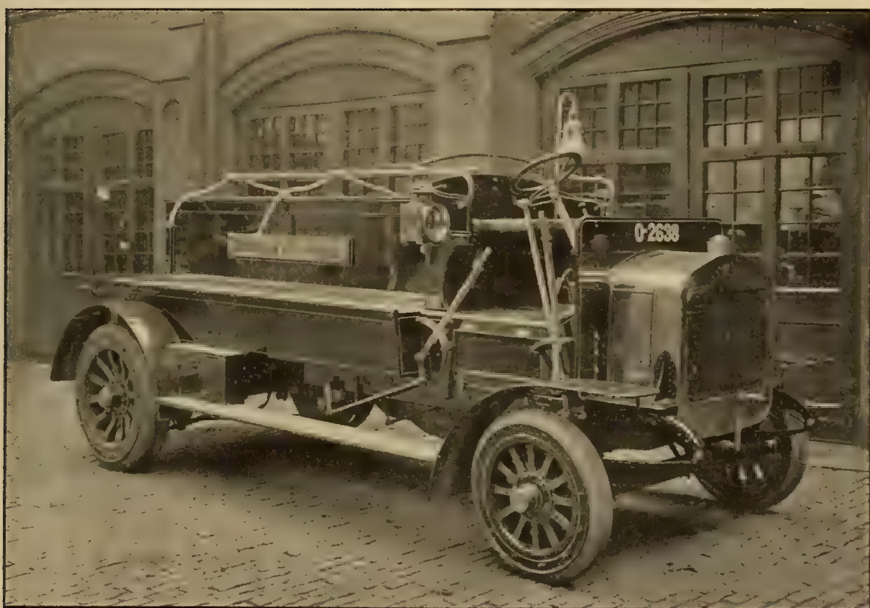


FIG. 21.—MOTOR FIRE TENDER. THE WOLSELEY TOOL & MOTOR CAR CO., LTD.

with the use of electric power for starting vehicles which are normally operated by a petrol engine, and for assisting a petrol engine on steep gradients, besides the proposals already carried out abroad, but not yet in Great Britain, to supply an electric omnibus with current from overhead conductors located alongside a road, special provision being made for the passing of one vehicle by another, or of moving from one side of the road to the other, to pass a cart or wagon.

E—MOTOR FIRE-TENDERS AND FIRE ENGINES.

Although not strictly of the class which come within the purview of this article, vehicles of this character may be referred to, and two examples of practice in this connection are illustrated in Figs. 21, 22 and 23.

Fig. 21 illustrates a fire-tender for conveying firemen to and from the scene of a fire, as constructed by the Wolseley Tool & Motor Car Co., Ltd. As this is mainly the adaptation of a suitable form of body to a standard chassis of this firm, further reference is hardly necessary, but this is indicative of the practice of several firms who have constructed vehicles of this class. In some cases an extension ladder, and various first-aid appliances, such as chemical fire-extinguishers, are carried.

Figs. 22 and 23 illustrate a motor fire engine constructed by Dennis Bros., Ltd., of Guildford. In this case the vehicle will carry a number of men, owing to the small space occupied by the motor equipment. The latter comprises a petrol engine of considerable power, with the necessary mechanisms for propulsion and control, and the pump is of turbine type, operated by the engine when not used for propulsion, and capable of discharging two or more jets of water to the required height.

In addition to motor fire engines of this class several other designs are in use, as well as motor fire escapes, wherein the propelling motor can be used for raising and maneuvering the ladder, but the

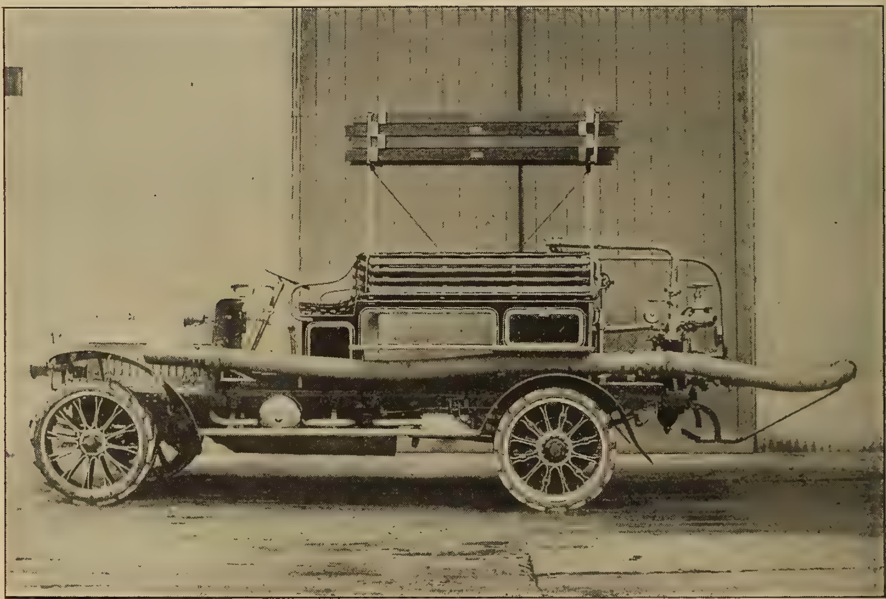


FIG. 22.—MOTOR FIRE ENGINE. DENNIS BROS., LTD.

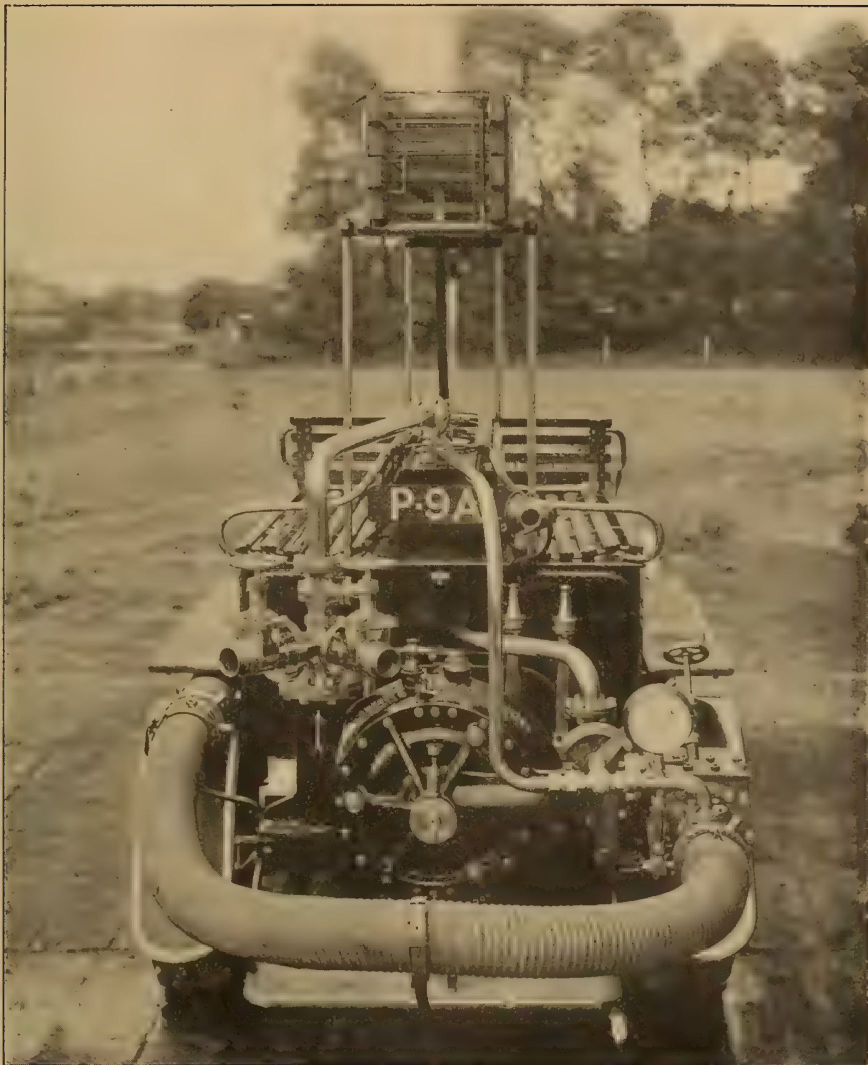


FIG. 23.—REAR VIEW OF MOTOR FIRE ENGINE. DENNIS BROS., LTD.

foregoing two examples sufficiently indicate the general features of practice.

In conclusion the writer would acknowledge his indebtedness to the various firms who have supplied particulars of their productions, and illustrations, for this article.

THE MODERN COTTON SPINNING FACTORY

By W. H. Booth

III. THE FINAL OPERATION OF SPINNING. INTERIOR ARRANGEMENTS OF A STANDARD MILL

This is the last of a series of three articles on the cotton-spinning factory. The final operation, that of spinning, is here described and descriptions of a few typical machinery lay-outs of up-to-date mills given. The first article, besides being of an introductory nature, described the processes of mixing and opening, the second one treating on the subsequent operations of carding, combing, drawing, slubbing and roving.—THE EDITOR.

SPINNING

The final operation in a spinning mill is that of spinning, for no notice need be taken in this article of the subsequent operations of winding the yarn upon larger bobbins and converting these into warps; for these operations, though often carried out in spinning mills, are properly preliminary processes in weaving.

Spinning is carried out on two varieties of machine, the mule and the throstle.

The latter is now practically obsolete, the ring frame having taken its place.

The throstle spinning frame was to the last no way different in principle and but little in mechanism, except in style and finish, from the original water frame as invented by Arkwright, and so called because it was driven by water power at the Cromford Mills, in Derbyshire, whither Arkwright fled from the machine smashers of his own county.

Arkwright's frame was simply a little roving frame, in which there was no positive geared driving of the bobbin. This was simply dragged round by the thread, and the thread was wound on the bobbin at the tension required to pull the bobbin round at its high velocity of several thousand turns per minute. Friction of the bobbin was purposely made large by interposing a strip of felt between the copping rail and the base of the bobbin. Thus, every bobbin was a little brake, and the power to turn one hundred throstle or flyer spindles was much greater than that required for the same number of mule spindles. But this clumsy frictional device made the machine very simple, and it consisted only of the three rows of draught rollers, a long tin roller carrying tapes or small cotton bands to drive the spindles, and a rising and falling rail driven by a heart-shaped cam, which caused the fully wound bobbin to be slightly barrel-shaped. The yarn spun on these frames could be spun hard, and was known as twist and made into warp. It could be hard spun because it was always under tension and could not snarl up. To-day the throstle frame does not appear in makers' catalogues. It has been superseded by the ring spinning frame Fig. 1. In this frame the yarn may either be twist or weft, for to a large extent the ring frame has displaced the mule also. Weft is spun upon wood pirns or upon paper tubes placed on the spindle. Twist is spun upon a pirn or headless bobbin, and the yarn comes off the full spindle in the form of a long, thin, barrel-shaped cop.

Upon the copping rail is a ring about 1½ inches diameter encircling the spindle, and round the edge of this ring fits loosely a little steel wire traveler through which is looped the yarn as it passes from the front roller to the spindle. The yarn drawn round by the rotation of the spindle drags the little traveling wire ring

rapidly round the edge of the ring, and the resistance thus set up gives the required drag upon the thread. This drag may be made slight by the use of light travelers, and soft yarn may be spun upon a ring frame. Since there is only a few inches interval between the spindle and the front roller, each bit of drawn roving, as it comes through the rollers, is promptly twisted into yarn. There is no draw between the two points, as in the mule, so that the evenness of the yarn depends entirely on the operations that have preceded spinning; and in modern mills, with their excellent preparation, the roving is of such even thickness that ring yarn is practically perfect, and what more can mule yarn be? Still, for the finer counts the mule still holds its own as a more delicately-worked machine. Much ingenuity has been expended upon the spindles of the ring frame, their bearings and the attachment of the little wharve or driven pulley, by which a little cotton cord communicates motion from the long tin-plate roller that extends all the length of the frame. The spindles are carried in a combined footstep and long collar oil-bath bearing screwed to the spindle rail. The wharve is attached to a tube which extends to the spindle and grips it above the top of the sleeve bearing, and the pirn comes down over this tube and grips it at the top of the spindle, so that pirn and spindle turn together.

Ring spinning frames are very narrow, and do not require wide passages between them. Consequently, as may be judged from the various illustrations, a very large number of spindles can be put upon a given floor space. In most mills it is usual to build the mill of such a breadth that two ring frames, of about 400 spindles each, will extend across the mill from passage to passage. The ring frame is a double-sided frame, there being about 200 spindles on each side driven from the tin rollers.

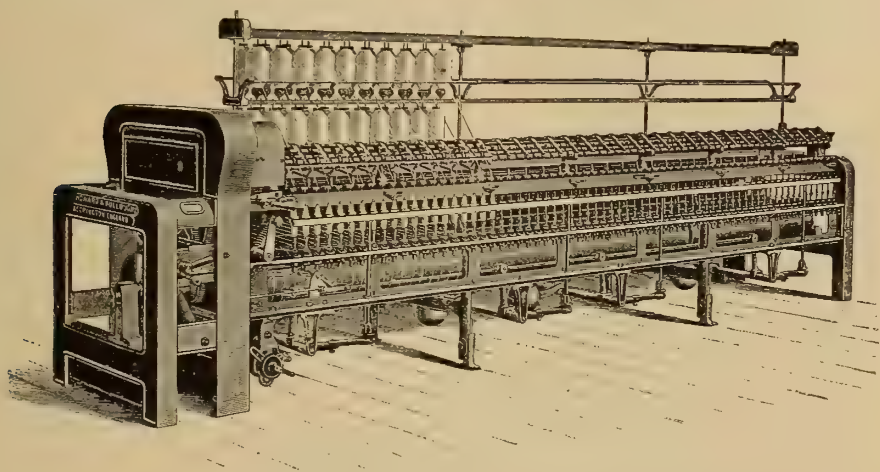


FIG. 1.—RING SPINNING FRAME. HOWARD & BULLOUGH, LTD., ACCRINGTON

There are two of these rollers, each of which is encircled by the spindle band, and a single band drives one spindle, the band making the circuit of the tin roller farthest away from the spindles it drives, and both entering and leaving each spindle wharve nearly horizontally. When a single tin roller was employed the angle of the band as it left the spindle wharve was very acute, and it was necessary to make the frames wider to reduce this. The double roller enables the frame to be made of minimum width, so that more spindles can be got upon

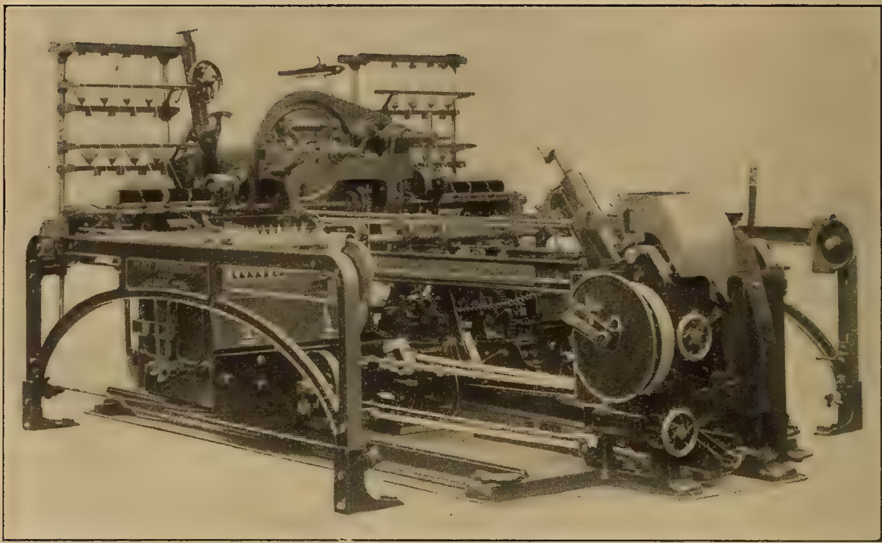


FIG. 2.—HEADSTOCK AND SELF-ACTING MULE. PLATT BROS. CO., LTD., OLDHAM

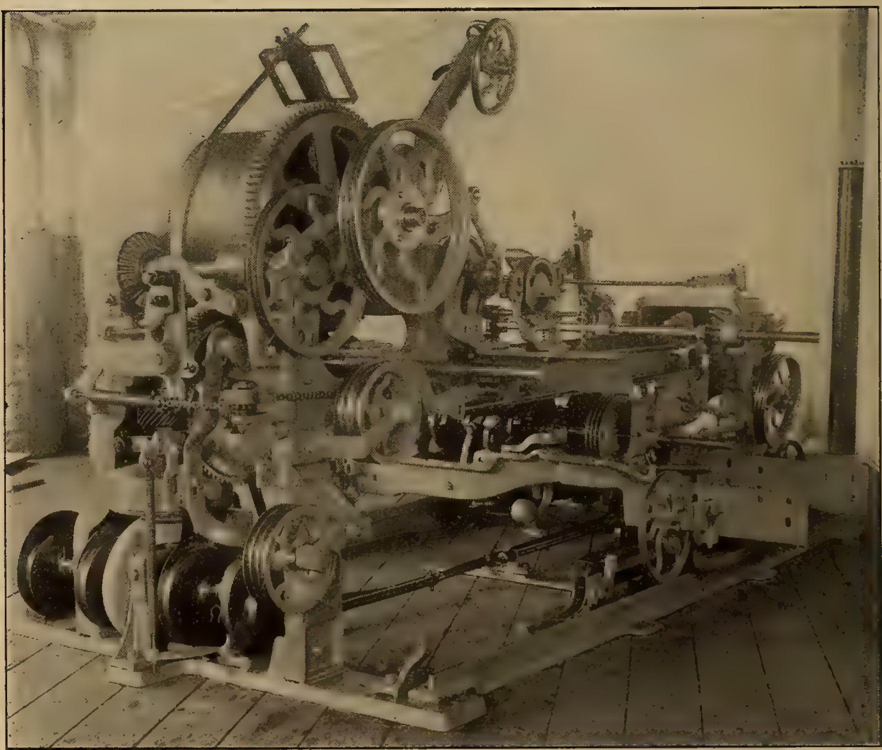


FIG. 3.—HEADSTOCK AND SELF-ACTING MULE. ASA LEES & CO., LTD., OLDHAM

a square foot of floor surface. The ring frame appears to be of American origin, devised to enable women to spin weft yarns; for, at least at one time, men could not be got to spin in America, and women could not spin on the mule. But though of American origin, the ring frame was brought to perfection in England, where it was introduced by Howard & Bullough, of Accrington, and Brooks & Doxey, of Gorton. Like the throstle, the ring frame is a continuous spinner, and the roving receives its twist as it issues from the front rollers. These are inclined forward towards the spindle tops, so that the issuing roving does not pull over a part of the circumference of the lower roller, as in the throstle. If it did so the twist could not run freely right up to the nip of the rollers, and the soft stuff would break easily. With the nip directly facing the spindle top the twist can run right up into the nip, so that the issuing roving is at once spun and does not break. This was a great improvement and made for the complete success of the ring spinning process.

The mule, Figs. 2, 3, 5, and 6, spins on a somewhat different principle. This machine was invented by Samuel Crompton, of Bolton, Lancashire, and it is not a continuous-acting machine. It draws out and spins about 5 feet of yarn, winds this upon the spindle, and proceeds to draw out another length of 5 feet, alternately spinning and winding up in turn. To effect this the bobbins of roving are carried, as usual, on light wooden pegs in a frame or creel behind the roller beam, and one or two threads of roving go to each thread of yarn. The rovings are led through wire eyes to the back pair of three pairs of rollers, the top rollers of each two back pairs being frequently plain metal and the front top roller being leather covered, all much the same as in slubbing and drawing frames, wherein, however, the top rollers are leather covered.

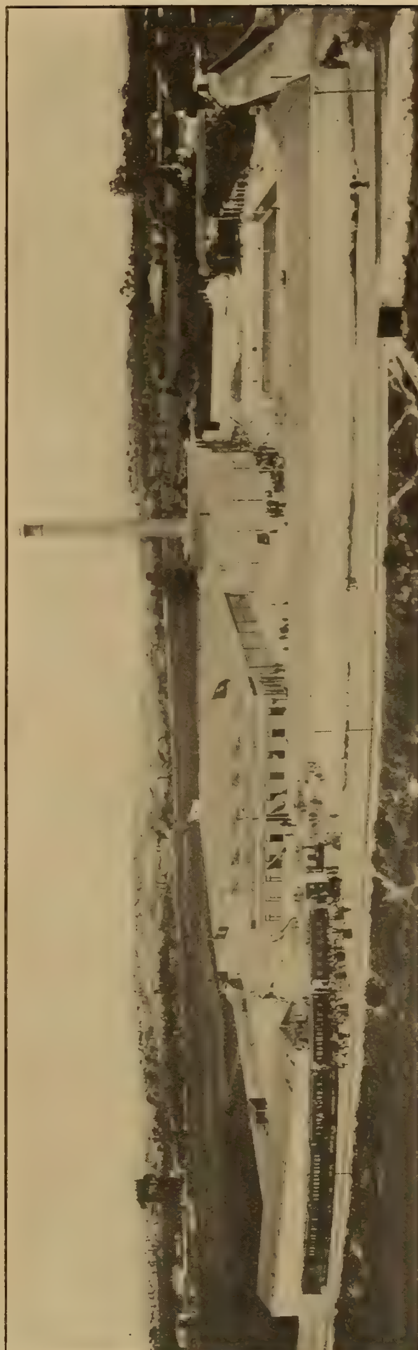


FIG. 4.—TYPICAL COTTON MILL IN BRAZIL. MACHINERY INSTALLED BY DOBSON & BARLOW, LTD., BOLTON

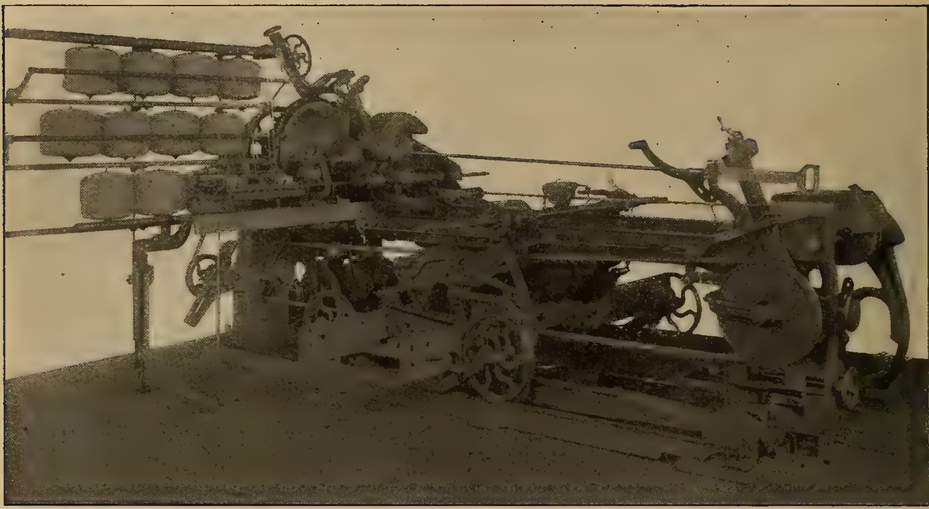


FIG. 5.—HEADSTOCK OF WASTE SPINNING MULE. ASA LEES & CO., LTD., OLDHAM

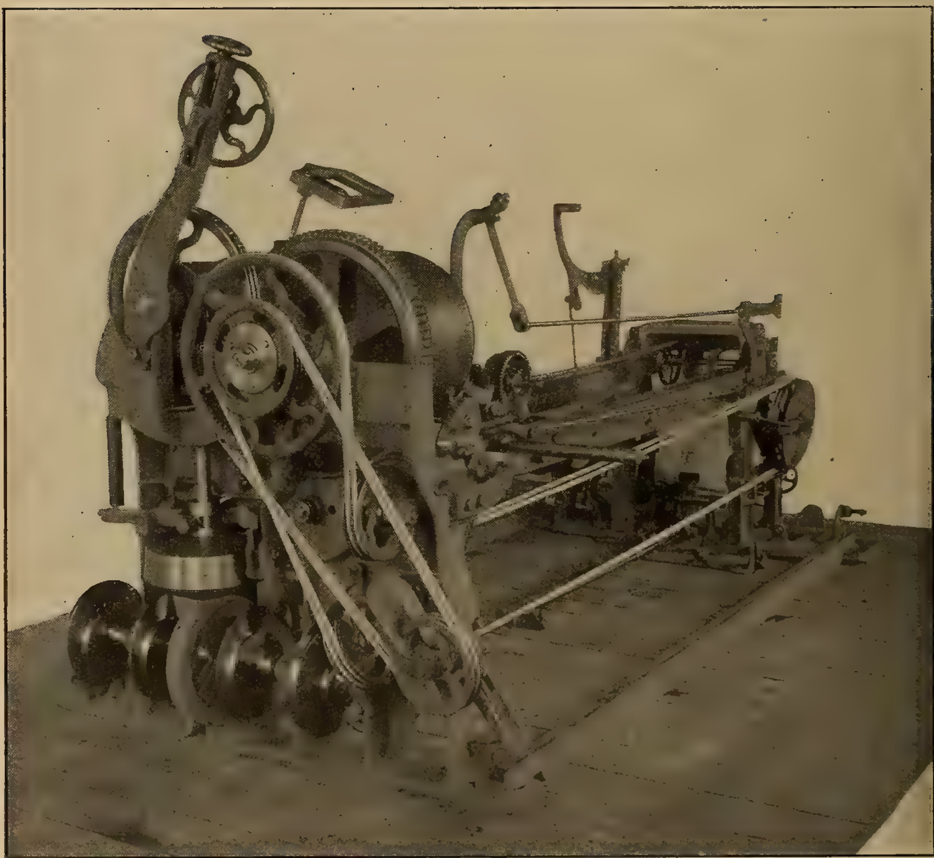


FIG. 6.—ANOTHER VIEW OF A WASTE SPINNING MULE HEADSTOCK

In the slubbing and roving frames all top rollers are leather covered and held down with weights slung over their spindles.

In all machines the bottom rollers are all fluted with narrow flutes, and, as they run against the upper leather rollers, these become marked by the flutes.

This marking may be prevented by fluting the bottom rollers somewhat unevenly in the pitch of the flutings, so that every part of the top roller some times takes the fluting and then does not take it, wear being even all round.

The drawn roving is delivered by the front pair of rollers and extends from them to the point of the spindle. It is an axiom with some spinners that, to increase production, the rollers should never stop moving. To secure this they are rotated quickly during the run out of the carriage, slowly when the carriage stops, and slowly during the run in of the carriage towards the rollers. The carriage carries the spindles, and there will be from 1,000 to 1,400 spindles in a mule, according to the gauge of the spindles or distance apart, which may be 1⅛ inches to 1⅝ inches. The carriage is moved out 64 inches, more or less, during which time the rollers turn out a somewhat less length of roving. The carriage also may move out some three or four inches while the front roller is practically standing still near the end of the draw. This carriage movement is called stretch. It is during this movement that the half-twisted yarn is stretched out so as to pull out all the softer parts and render the yarn even. In the spinning of the finer yarns the carriage must also stand still at its extreme outward run, while the spindles continue to rotate and put into the yarn the necessary number of turns. The number of turns per

FIG. 7.—INTERIOR OF PREPARING ROOM OF MILL SHOWN ON PAGE 585

inch of length varies as the square root of the counts of the yarn. Thus, a yarn of 16's counts will have fifteen turns per inch and yarn of 64's counts will have thirty turns for the same degree of hardness. The standard twists is $3\frac{3}{4}\sqrt{\text{counts}}$ for American twist and $3.606\sqrt{\text{counts}}$ for Bolton counts.

A yarn of 120's has nearly forty turns per inch, so that with a stretch of 64 inches the spindle must rotate turn and wind up the yarn, the said wire moving upwards so as to wind evenly on the cop. Some allowance is made by the fact that the yarn passes over another long horizontal wire similarly held, but on weighted arms. This wire gives a uniform tension to the wound yarn, and is free to move and yield to excess tension or take up undue slack. But the point end of the cop is conical, and the winding of the yarn upon it

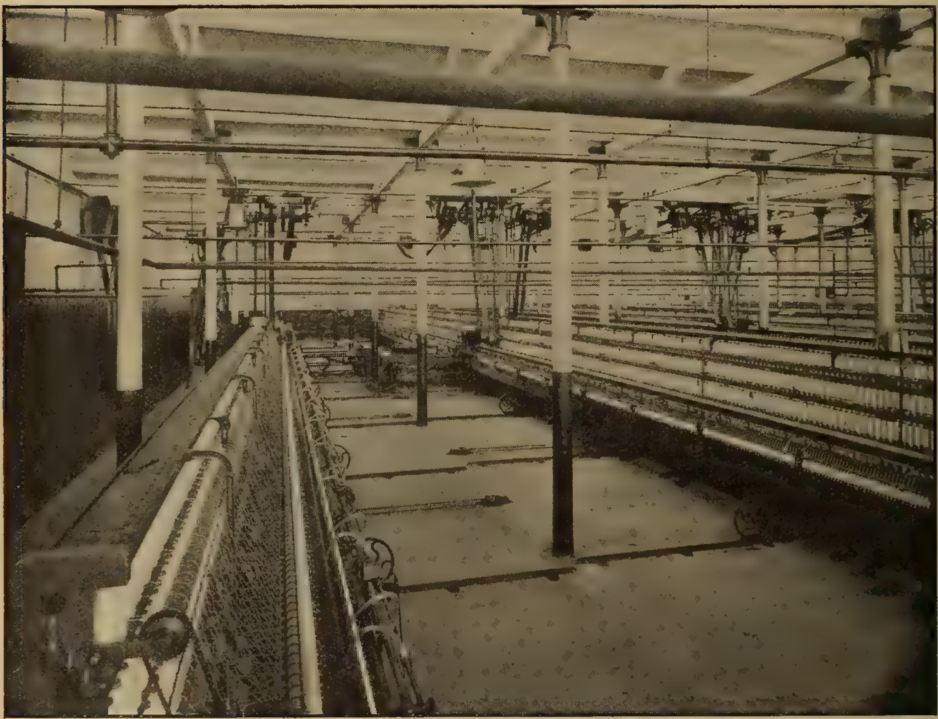


FIG. 8.—SPINNING MULES. DOBSON & BARLOW, LTD.

2,560 times for each draw-out of the carriage, and some of this has to be put in after the carriage has run out. Spinning completed, there are a few turns of yarn on the bare spindle between the top of the cop and the spindle point. This must be removed, and it is removed by causing the spindles to turn backwards. Next the yarn must be wound on the cop nose. A long wire descends on the stretch of yarn and the carriage begins to run in and the spindles

has to be regulated so that, as the winding approaches the smaller diameter of the cone, the spindles shall turn correspondingly quicker. Further, until the cop has been formed to its full diameter, the winding has further to be adjusted so as correctly to form the cop shape from the start upon the bare spindle. Now all this has to be, and is, automatically effected by the mule itself, and the slight play of the top tension wire is all that is permitted from per-

fect action of the mechanism. The cop is formed, and the machine varies itself to do this. Arrived at full nose shape, the machine then becomes practically of equal winding action after each draw, except that, as the cop grows towards the thinner diameter of the spindle, a certain additional small winding speed of the spindles must be given to compensate for this. For very fine counts this complete automaticity of the mule in winding has only lately been perfectly secured, and the faller wire which regulates the winding is operated by hand, and is a very skillful bit of work. But in ordinarily fine counts the operative has no special skill of hand to display. The machine does everything but piece up broken ends.

The long carriage is divided into two nearly equal halves, the two together about 130 feet long, and these two long carriages run on wheels upon rails laid on the floor, and are drawn equally to and fro by ropes worked over scrolls on a shaft behind the roller beam, which shaft extends to the central headstock, in which is concentrated all the gearing and movements by which the above complex series and combinations of operations are effected. It would require many pages adequately to describe the self-acting mule, so called because this invention of Crompton—an ancestral relative of the present writer—was a sort of hybrid between the water frame of Arkwright and the spinning jenny of Hargreaves.

FIG. 9.—ELECTRICALLY-DRIVEN SPINNING FRAMES. DOBSON & BARLOW, LTD.

Crompton left the mule somewhat as it is used to-day—for very fine spinning. It is to Richard Roberts, of Manchester, that the fully automatic or self-acting mule is due. Hargreaves employed a stationary frame of spindles, and the rovings were run out from a fixed creel and through a bar, which nipped them after a

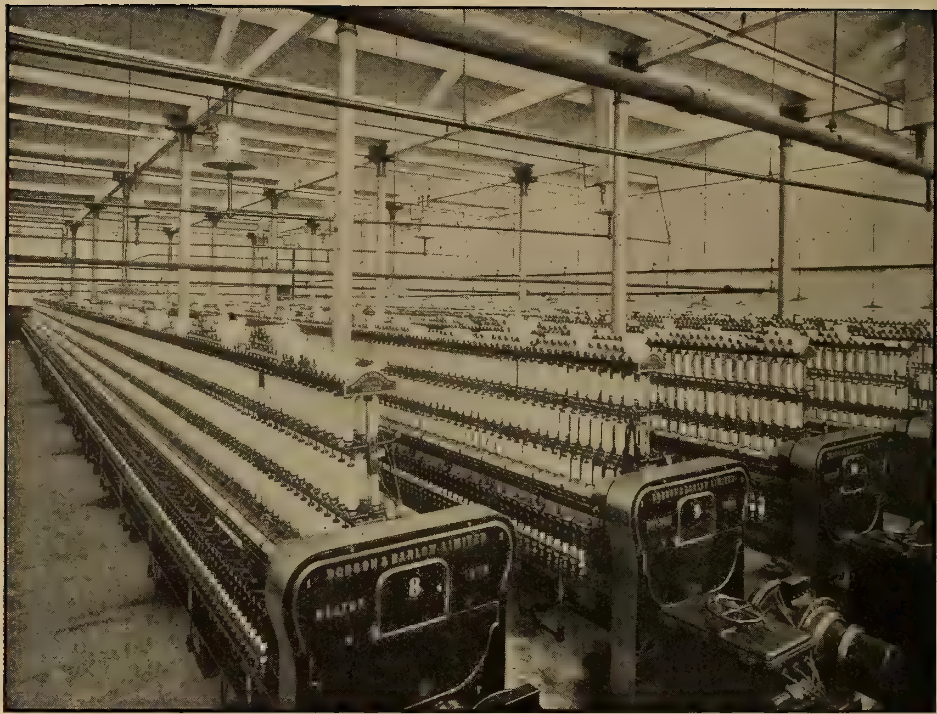


FIG. 10.—ELECTRICALLY-DRIVEN RING SPINNING FRAMES. DOBSON & BARLOW, LTD.

given length had been given out, and this bar was moved still further from the spindles after the rovings were nipped fast. Thus there was the drag or stretch on the soft, partly-twisted yarn. But Crompton fixed this bar and added draw rollers upon it, and put the spindles on the moving carriage and produced the hybrid mule which Roberts perfected and placed much as it is to-day, a very marvel of mechanism.

Asa Lees & Co., Platt Bros. & Co. and other makers now make the mule to spin counts as fine as 300's from Sea Island or Egyptian cottons and to be automatic. Such fine counts were once spun only on hand-winding mules.

In this complex machine, a part of which is moving to and fro upon the floor, movements of several orders have to be communicated to the spindles and faller wires on this running carriage from the fixed part of the machine. This is effected by rim wheels, with rope bands so arranged that the carriage rims run in a reduplication of the rope bands, and thus are self-compensating for carriage movement as regards tightness. All other movements and compensations of speed for different speeds of the spindles are made in the fixed headstock gearing. Very various are the mechanical means by which the many different movements are effected. There are scrolls of increasing diameter on which are wound the ropes which haul the carriage in and out at the proper speeds, starting gently and stopping gently, owing to the varying spiral of the scroll. These are variously-sloped rails on which run the rollers of the levers which move the faller wires. There are other scrolls for spindle winding, varied in the copping motion by a peculiar quadrant gear with a winding chain of varying length, and there are numerous clutches and other involved movements for the many motions required.

The illustrations of parts of the

mule will serve to tell of its complexity, even though not readable by the non-expert. See Figs. 2, 3, 5 and 6.

The relative proportions or numbers of the various machines in a factory is most important. A thousand spinning spindles turning out so many hanks of yarn consume so many hanks of roving, and this is made from a nearly equal weight of slubbing, of drawing sliver, of combed sliver, carded sliver or scutcher lap. Each process must turn out the same weight of stuff as the next following process plus a small percentage for waste or spoiled material. Properly proportioned, there is very little stock of material between each process. No machine ought ever to stop for lack of following supplies of what to it is its raw material. Machines are designed to produce certain average weights, and their average hourly output can be closely foretold. But any lack of proportion can readily be corrected. Thus, if we suppose that there is a shortness of supplies for the first slubbing operation, a very slight variation can be made in the velocity with which cotton is fed to the first scutcher. This will produce a somewhat heavier lap, and the following carded sliver and drawing sliver will, in turn, be heavier per card. The back roller of the slubbing frame can then be made to run rather less quickly, when it will still supply an equal weight to the second roller; but the draft between the two rollers will be slightly greater, so as to counteract the heavier sliver. At every process corrections can be made for slight discrepancies, but the general lay-out of a mill to spin 50's would be quite wrong for a mill intended for 20's. As an example of machinery required for spinning such yarns as average 30's on self-acting mules or ring frames, with the approximate calculated production at each process, the sliver weight, spin-

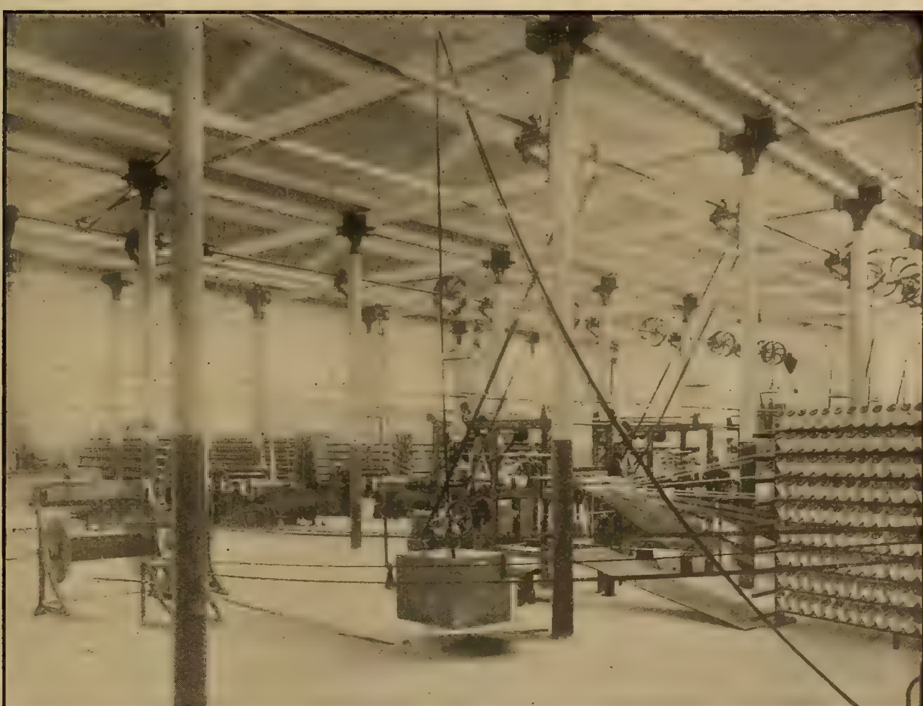


FIG. 11.—FINISHING ROOM. THE PROCESSES OF WARPING AND BEAMING

TABLE I.—LIST OF SPINNING MILL MACHINERY

	Hank of Roving.	Speed.	Production per Week of 55½ Hours.
108 single cards 45 inches wide on wire 50-inch cylinder, 106 flats 1⅜ inches wide	0.15	170 revolutions, cylinder	774 lbs. = 116 hks. per card. per card.
27 drawing frames, 2 heads of 4 deliveries = 72 finishing deliveries	0.13	350 revolutions of front roller 1⅛ inches in	1,150 lbs. = 149 hks. per delivery per delivery per spindle. per spindle.
9 slubbing frames of 96 spindles 10 x 5½-inch bobbins, 19-inch staff	0.625	600 revolutions of spindle	94.8 lbs. = 59.2 hks.
17 intermediate frames, 140 spindles, each 10 x 4⅜-inch bobbins, 26⅜-inch staff	1.60	750 " "	34.1 lbs. = 54.5 hks.
42 roving frames, 180 spindles, each 8 x 3⅝-inch bobbins, 20½-inch staff	4.25	1,100 " "	10.6 lbs. = 45.1 hks.
72 S. A. mules, 1,100 spindles each, 64-inch stretch	30's av.	10,000 " "	1.03 lbs. = 31 hks.
or, 120 ring spinning frames, 440 spindles each, 2½-inch pitch, 1⅝-inch rings, 6½-inch lift	30's	9,000 " "	1.5 lbs. = 45 hks.

dle speeds, etc., let it be assumed there are 79,200 mule spindles for 28's to 32's (average 30's) twist-spun counts at 31 hanks per spindle, calculated to produce 79,566 pounds of yarn per week of 55½ hours' working, from American cotton and single roving of 4¼ hanks.

Or there would be 52,800 ring spindles for the same counts producing 45 hanks per spindle, or 79,200 pounds of yarn, from the same roving. This production would require three hopper bale breakers 36 inches wide; three hopper feeders with filling apparatus, 36 inches wide; three single Creighton cylinder openers with pipe connection to the exhaust opener or bale machines; also three in number, 48 inches wide, for 46-inch laps, with lattice feeder 4 feet centres and patent dust trunks.

Following these come seven single scutchers 46 inches wide for 45-inch wide laps, and a feeder lattice for four laps. The finished lap will

TABLE II.—LIST OF MACHINES FOR A STANDARD MILL FOR OLDHAM COUNTS

Quantity of Machines.	Kind of Machine.	Spindles, etc., per Frame.	Gauge, etc.	Total Number of Spindles, etc.	Production per Spindle in 10 Hours.	Total Production in 10 Hours.
1	Bale opener, with mixing lattices, etc.					
4	Combined exhaust openers with porcupine feed table and hoppers.					
7	Intermediate scutchers.					
7	Finisher scutchers.					
140	Revolving flat carding engines	....	37 inches on the wire	....	125 lbs. per card	17,500 lbs.
30	Drawing frames	2 heads each 5 deliveries	16 inches	100 finishing deliveries	175 lbs. per delivery	17,500 lbs.
10	Slubbing frames	104 spindles.	4 spindles in 17½-in. gauge, 10-in. lift	1,040 spindles.	16.82 lbs. per spindle of 0.6 hank	17,500 lbs.
20	Intermediate frames	142 spindles.	6 spindles in 19½-in. gauge, 10-in. lift	2,840 spindles.	6.16 lbs. per spindle of 1.5 hank	17,500 lbs.
56	Roving frames	180 spindles.	8 spindles in 20½-in. gauge, 7-in. lift	10,080 spindles	1.73 lbs. per spindle of 4.5 hank	17,500 lbs.
175	Ring frames	400 spindles.	2⅝ gauge, 1⅝ ring, 5-in. lift	70,000 spindles	0.25 lbs. per spindle of 30's counts	17,500 lbs.

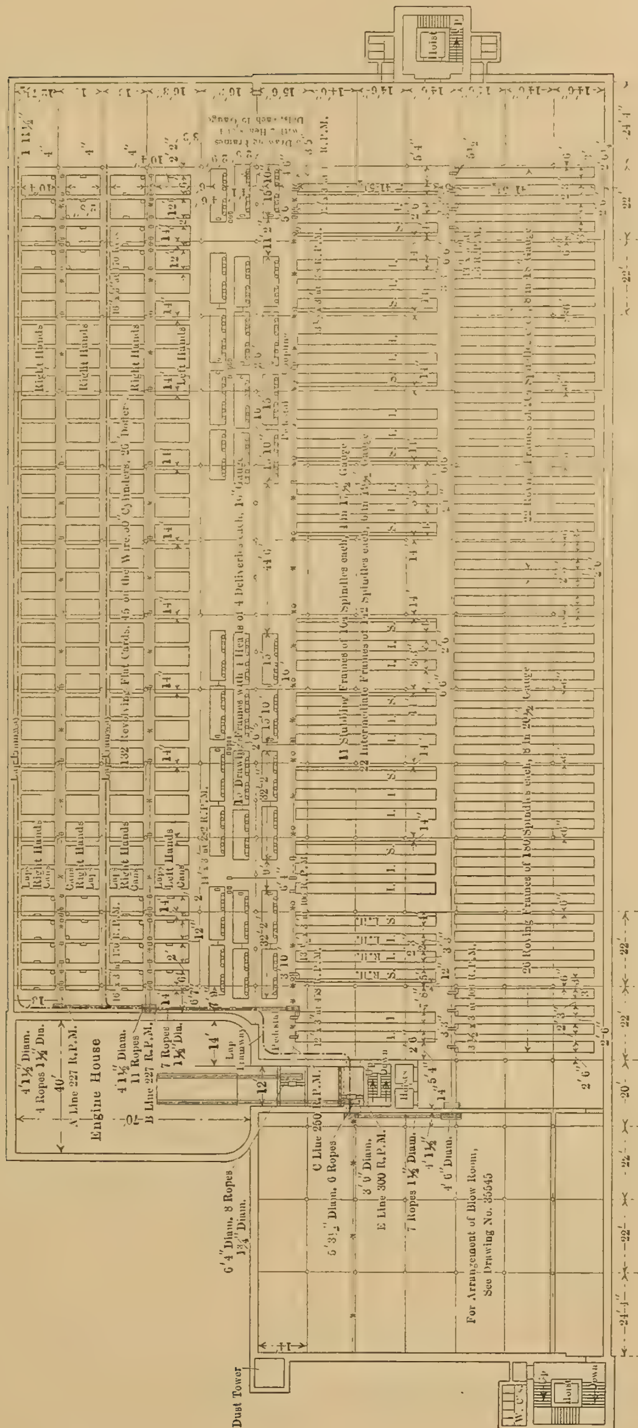


FIG. 12.—CARD ROOM, FIRST FLOOR OF THE STANHILL MILL AT OSWALDTWISTLE, FITTED UP BY HOWARD & BULLOUGH, OF ACCRINGTON

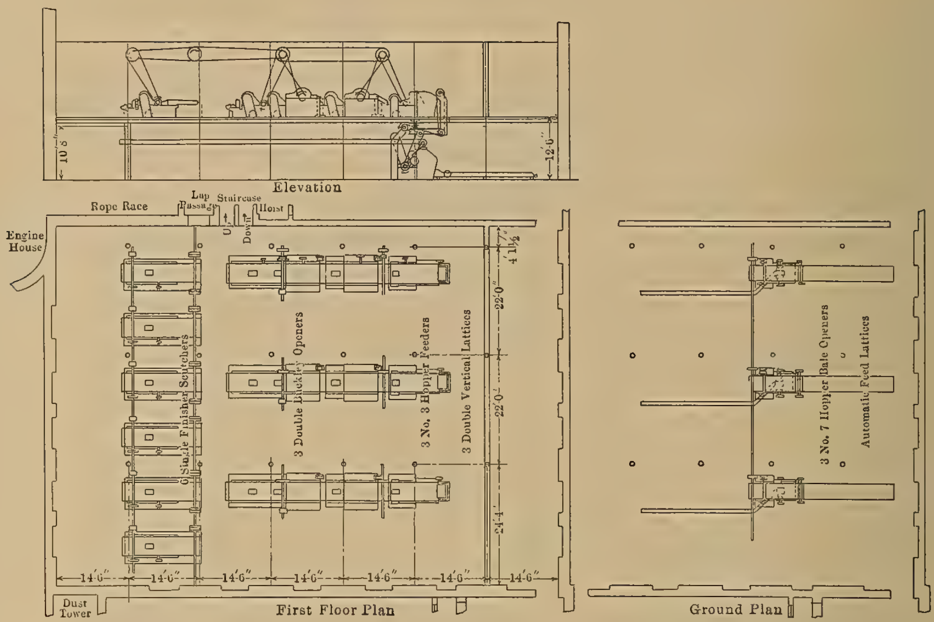


FIG. 13.—GROUND PLAN, FIRST FLOOR PLAN AND ELEVATION OF THE STANHILL MILL AT OSWALDTWISTLE. FITTED UP BY HOWARD & BULLOUGH, OF ACCRINGTON

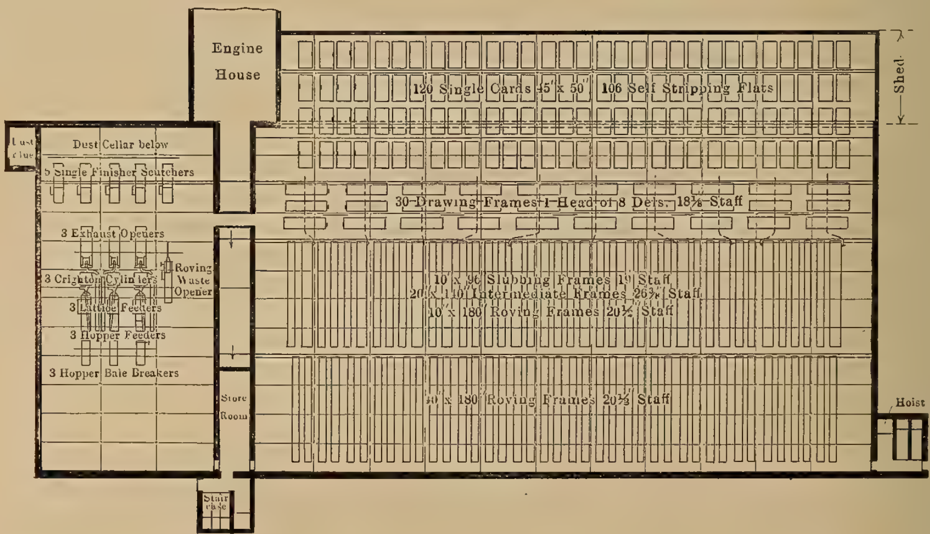


FIG. 14.—MODERN MILL TO CONTAIN 106,176 MULE SPINDLES AND PREPARATION FOR COUNTS 30'S TO 40'S TWIST AND WEFT, FROM AMERICAN COTTON. PLATT BROS., OLDHAM

First spinning room contains 28 x 1,344 S. A. mules, 1⅛" distance, 64" stretch. Second spinning room contains 28 x 1,344 S. A. mules, 1⅛" distance, 64" stretch. Third spinning room contains 28 x 1,104 S. A. mules, 1⅜" distance, 64" stretch.

weigh 14 ounces per yard length. With this will go the roving waste opener and feeding machine. This completes the blowing room machinery, after which comes the machinery as per table I.

Each process is allowed on the above 1 per cent. loss from the card sliver to the spindle point as a suitable allowance for waste.

is nominally 96,000 pounds. Since the output of a spinning frame is the product of the counts' weight and the front roller speed, the general output of a mill varies inversely as the counts, and the output of a very large factory spinning fine counts is quite moderate in weight. The labour cost of yarn must vary also very closely directly as the counts, as also must

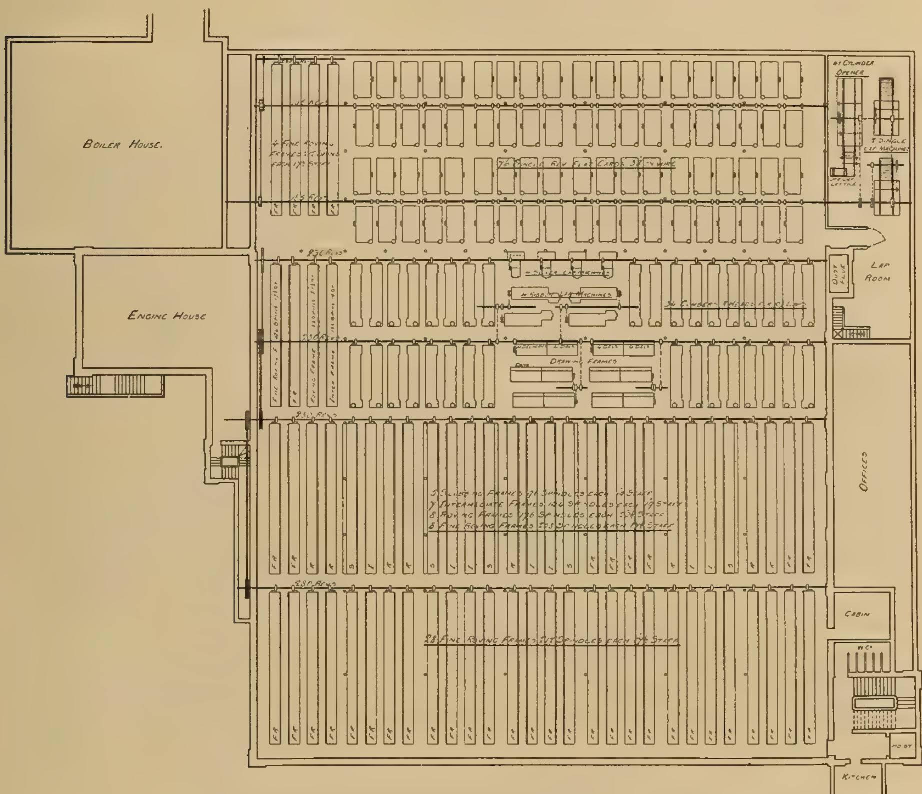


FIG. 15.—CAIRO MILL. MACHINERY BY ASA LEES & CO., LTD.

Different machine makers have their different ways of solving the problem of a factory equipment, but they do not differ very far in their proportions as to machinery and output.

In the second table are given the similar estimates of another firm of machine makers. This latter also may be described as a standard mill for Oldham counts, so called, though Oldham has taken to finer counts now to a very large degree. For this mill the weekly production

general charges, fuel and other labour. The price of yarn when spun is, therefore, made up of the cost of cotton per pound plus, approximately, $\frac{C\,x}{10}$, where C is the counts and x is the total mill cost of No. 10's. In very fine yarns the latter item may very much exceed the former. In coarse counts the cost of the cotton itself remains the chief expense. Hence the coarse spinner is more heavily hit when prices of raw cot-

ton go up than is the fine spinner, and the coarse spinner must also be more on the alert in respect of loss of weight by dirt and waste; for this will affect his profits more than it would where the labour forms a greater proportion of the cost of a pound of yarn.

The Stanhill Mill, at Oswaldtwistle, Figs. 12-13, has been fitted up throughout by Howard & Bullough, of Accrington. It contains 70,584 ring spindles spinning counts from 10's to 50's. The top floor contains, besides ring frames, warping and winding machinery, which does not come into the purview of this article. The second floor contains only ring spinning frames; the first floor contains the cards, 132 in number, 88 finishing drawing-deliveries, 11 slubbing frames of 104 spindles, 22 intermediate frames of 142 spindles, 26 roving frames of 180 spindles, and 22 of 204 spindles. In the blowing room, on the first floor, are 3 openers, with hopper feeders and 6 finishing scutchers, and on the ground floor the hopper bale openers, 3 in number, and a large cotton store. The counts spun average about 30's.

In order to place all the carding engines and speed frames on one floor, a very considerable shed extension of the first floor has had to be made; this is shown beyond the row of half-spaced pillars, the cards being under the unlighted shed roof. It will be noted that the drawing frames are spread along the front line of the cards, so as not to involve too much movement of sliver cans. The slubbing and intermediate frames are similarly interspaced, one and two along the line of drawing frames, and the roving frames then form a third long line.

The laps travel in from the blowing room on a single-line train, the blowing room being on the same floor

FIG. 16.—CARD ROOM OF CURZON MILL, ASHTON-UNDER-LYNE. MACHINERY BY JOHN HETHERINGTON & SONS, MANCHESTER

beyond the rope race and small hoists and subsidiary stairway. The unoccupied spaces serve for accumulations of sliver cans, skips of slubbing or roving bobbins, full or empty, and as passageways. The spinning room, nearly 102 feet wide, provides for two frames of rings across it of 432 and 408 spindles, respectively, with a double tram line between the frames, the spindles running at 9,000 revolutions per minute and the frames being all driven from a single line shaft with gallows frame pulleys.

the first and third head; whereas in Fig. 15 or Fig. 12 the three heads are in series, one behind the other. The third draw of the alternative is again opposite way from the second, so as to deliver just behind a group of slubbing and intermediate frames.

A few intermediate frames are also interspaced with the fifty roving frames.

The engines are of 1,520 horsepower, or sufficient for about 72,000 ring spindles.

As a modern Oldham mill for fine

FIG. 17.—BROADSTONE MILL, REDDISH; 125,000 MULE SPINDLES, COUNTS 40'S TO 110'S. MACHINERY BY JOHN HETHERINGTON & SONS, MANCHESTER

The different length of the two rows of frames is to suit the plan of the mill, the long row extending to the face of the hoistway and the tramway track being in one straight line throughout the length of the building.

Arrangements of machines may be varied according to opinion. In one card-room arrangement the drawing frames are placed differently, and so that the material travels from right to left through the first head, or, *vice versa,* left to right, through the second head placed in the same line as

counts with combed sliver, the Cairo mill, Fig. 15 was fitted up by Asa Lees & Co., Ltd. This is a mule spinning mill, as may be inferred from the counts, which vary from 120 to 136, as seen at the time of the writer's inspection. The drawings show well the shed extension of the ground floor for the accommodation of the whole of the preparation machinery on one floor. The small amount of blowing room machinery indicates the comparatively small consumption of cotton by the 72,268 mule spindles.

The sliver lap machines, ribbon lap machines and combers are seen arranged between the seventy-six revolving flat cards and the drawing frames. The speed frames, as slubbing frames and others are called, are of four sizes, namely, 4 first, 7 second, 11 roving and 38 Jack or fine roving frames for reducing down to about 16 hank for the finer counts spun. There are only 32 finishing deliveries of drawing, and there are 24 combers with 4 sliver and 4 ribbon lap machines; but there are 72,268 mule spindles made up of 18,732 spindles of 1⅛ inches gauge in each of the first, second and third spinning rooms, and 16,072 spindles of 1 5/16 inches gauge in the fourth spinning room.

As an example of general construction may be cited the Imperial Mill, Blackburn. Fireproof throughout, the floors consist of steel beams with a brick vaulting covered with spruce boards, and carried by cast-iron columns and brick walls. The windows are large in area. The cellar serves as a cotton store, warehouse, yarn cellar, dust and waste chambers, general storeroom, and as a reeling room. There is a loading way which admits lorries under a projection of the blowing room in the centre of the mill. On the first floor is the card room, extended on the south side by a narrow shed building, as elsewhere described as being usual practice to enable all preparation machinery to be placed on one floor. The second floor is filled with ring frames, as also a part of the top floor, which contains winding, warping and beaming machines.

The engine house is projected beyond the south wall, and measures 77 feet 6 inches by 36 feet wide, with a rope race projecting into the mill and extending to the roof. The engine room walls and floors are tiled.

FIG. 18.—KEARSLEY SPINNING CO., LTD., BOLTON; 120,000 SPINDLES, 60'S TO 120'S COUNTS. MACHINERY BY JOHN HETHERINGTON SONS, LTD., BOLTON

The boiler house is alongside, and contains four 30 ft. × 8 in. Lancashire boilers and a Green's economizer of 384 pipes. The pump house adjoins. The chimney is 210 feet high and 9 feet inside diameter.

There are in the blowing department 3 hopper bale openers, 3 hopper feeders, 3 exhaust openers, in the cellar; 6 intermediate and 6 finisher scutchers. In the card room there are both fine and coarse preparation machines, namely, on the fine side 52 revolving flat carding engines, 15 drawing frames, 5 first slubbing, 8 second and 20 roving frames; and

on the coarse side the same numbers; while in the fine spinning department there are 44 twist frames of 400 spindles each and 44 with 420 spindles, the gauge being 2⅜ inches with 1½-inch rings. On the coarse side there are 36 ring frames of 420 spindles and 36 of 400 spindles and 4 of 384 spindles, with a gauge of 2⅜ inches and rings of 1⅝ inches. There are 14 winding frames and 19 beaming frames.

The course of the fibre is from the bale openers to the hopper feeders, thence to the exhaust openers, where the first laps are made. There is no handling of the cotton after it is pitched in bulk into the bale opener. The laps are run on a tram car to the rear of the carding engines. The rope race divides the card room into two distinct halves, fine and coarse. The rovings are raised by a lift at each end of the mill into the spinning rooms.

The exhaust openers have each a combined scutcher beater and produce laps which are placed on the intermediate scutchers, which form laps for the finishers.

In the carding engines 43 of the 110 flats of each engine are always working; there is a slow motion for use when grinding the cylinder and doffer wire clothing and for slowing when piecing sliver. The three heads of draw frames are in series, one frame behind another, and all have the makers' electric stop motion.

The speed frames have three rows of rollers and a full bobbin stop motion, and the ring spinning process have the Rabbeth flexible spring spindles, tin rollers carefully balanced and sliver traverse motion for equalizing wear on the leather rollers, anti-balloon apparatus and girder section spindle rails. All wheel teeth are machine-moulded or cut, and the machinery is made throughout to

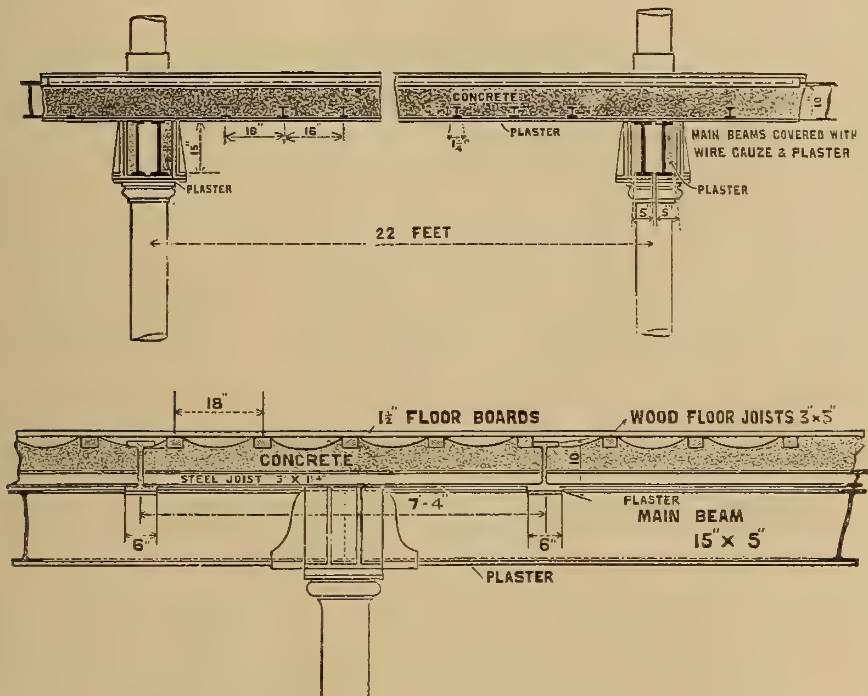


FIG. 19.—CEILING WITH STEEL GIRDERS, AND FLAT CONCRETE CEILING WITH SMALL STEEL JOISTS, BAYS 22 FEET X 14 FEET. PLATT BROS., OLDHAM

gauge and template, with interchangeable parts.

The engines required to drive this mill of 66,736 ring spindles, preparation, etc., have an economical capacity of 1,700 horse-power, and are of horizontal, four-cylinder, triple-expansion type, capable of 2,000 horse-power if required. They are of two-crank, double-tandem type with cylinders 23 inches, 38½ inches and two 42½ inches diameter with a 66-inch stroke, the two-horse-power cylinders being placed in the rear. The speed is 60 revolutions per minute and the boiler pressure 180 pounds. The first two cylinders are jacketted, and there is a steel-plate jacketted reheater between them.

The rope rim is 27 feet diameter, is grooved for 38 ropes 1¾ inches diameter, and weighs 65 tons. There is a jet condenser and an air pump to each side, worked by the usual lever from the tail rod, and the engine can be stopped from any room in the mill in case of accident.

The shafting consists of a line in the cellar with two ropes; two card-room shafts, each with six ropes; one spinning-room shaft with eighteen ropes, and a six-rope line in the top room.

The shafting is all steel, and has ring lubricated bearings. The two lighting dynamos are rope-driven from the card room shafting, and fitted with friction clutches for starting and stopping. The ropes are of the Lambeth type, with a cover of ten twisted cords of cotton yarn. The peculiarity of the Lambeth rope is its four strands, with a small central core on which no stress comes. Ropes are usually three-stranded.

Throughout the mill is a full system of automatic sprinklers fed from a fly-wheel pump, and there is a water tank of 7,500 gallons capacity in the dust tower. This also sup-

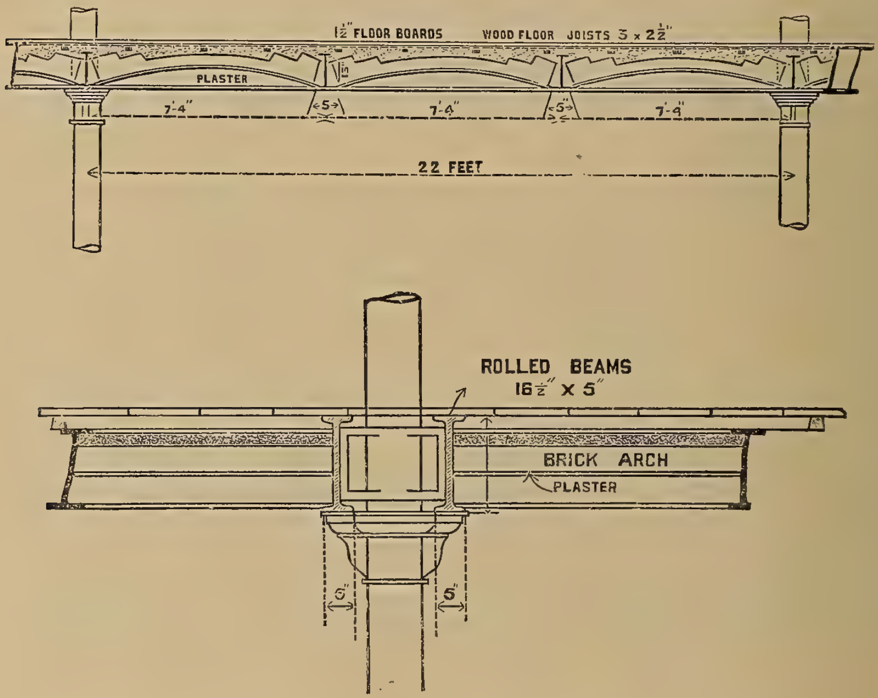


FIG. 20.—CEILING WITH STEEL DOUBLE MAIN GIRDERS, STEEL CROSS BEAMS, AND BRICK ARCHES, BAYS 22 FEET X 22 FEET. PLATT BROS., OLDHAM

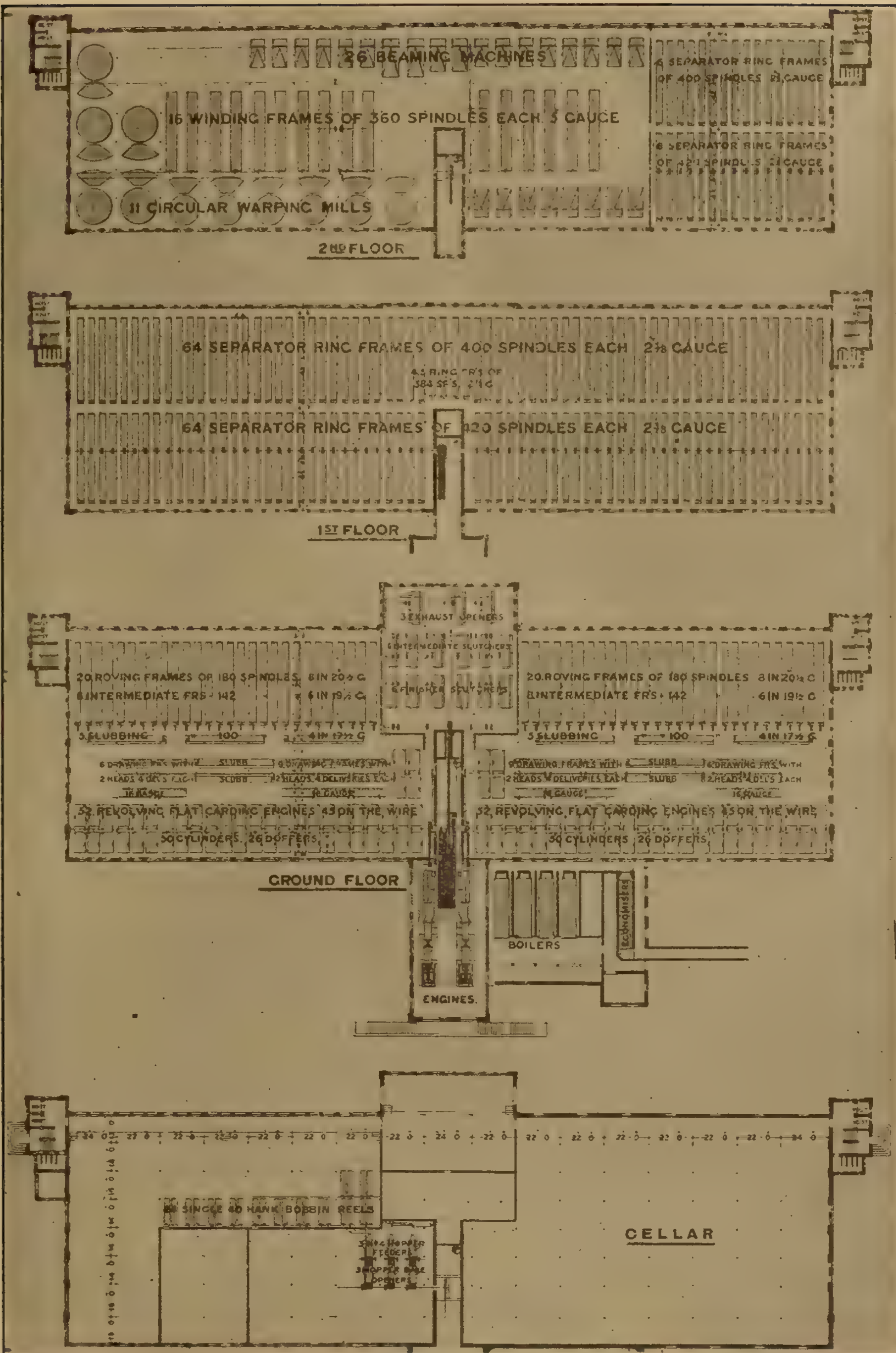


FIG. 21.—MODERN LANCASHIRE RING SPINNING MILL, 67,136 SPINDLES. HOWARD & BULLOUGH, LTD., ACCRINGTON, ENGLAND

plies the sprinklers. The pump also supplies hydrants at points round the mill and on each landing of the staircases. All necessary pressure gauges, valves and name plates are supplied.

There are three lighting dynamos, two driven off the main engine and one driven by a separate small engine. There are two circuits, a main and a pilot, the main current only being put on for working hours and the smaller circuit for lighting the employees in and out.

This mill may also be taken as a fair example of the modern mill. The machinery throughout was supplied by Messrs. Howard & Bullough, of Accrington, to whom the author is indebted for drawings and information in preparing this article. Since the Imperial Mill was built the top room has been filled with preparation and spinning machinery, so that the mill now contains 90,812 spindles, and a shed has been erected outside for the displaced machinery.

Messrs. Platt Bros., of Oldham; Messrs. Dobson & Barlow, of Bolton; Messrs. Asa Lees & Co., of Oldham, and Messrs. John Hetherington & Sons, of Manchester, all supply machinery of similar high class for the complete equipment of mills throughout, and have, equally, placed the author under obligation by their supply of illustrations and information.

In the limit of a brief article it has been impossible to do more than make selections for illustrations, one machine from one firm, another from a second, and so on; and there are, in addition to the above-named firms who make the whole range of machines, such firms as Messrs. Lord Bros., of Todmorden, who originated the piano-regulating motion; Messrs. Taylor, Lang & Co., of Stalybridge, who made a specialty of the mule and of blowing-room machinery; Messrs. Tweedales & Smalley, of Castleton-by-Rochdale, who make carding-room machinery and ring frames; Messrs. Brooks & Doxey, of Manchester, who make almost the full range of spinning and doubling machinery; while there are scores of firms making a few machines or one class of machine or accessories, such as spindles, bobbins, card wire cloths, and the thousands of small details which appertain to the spinning industry, which has now extended until there are probably 55 million spinning spindles in Great Britain.

And to drive all this machinery there are boilers and steam engines made by numerous world-known firms, such as Hick Hargreaves, Musgraves & Woods, of Bolton; Yates & Thom, of Blackburn; Saxons and Buckley & Taylor, of Manchester and Oldham, and many others, consideration of which properly belongs to a special article.

THE VALUE OF THE MODEL EXPERIMENTAL BASIN IN SHIP DESIGNING

By Robert G. Skerrett

THERE is probably no more picturesque example of mechanical power than the sight of a big ship steaming through a tumbling sea, tossing hundreds of tons of water aside as she forges ahead with the self-sufficiency of a mighty Titan. It is hard for the average layman to realize that things are not actually as they seem: that the great craft is *not* pushing violently aside her own weight of water only, to draw it in again after her with a duplicate expenditure of power. The fiction of this deceptive picture was exposed forty years ago by the late Dr. William Froude, of England, who, by means of certain epoch-making experiments with small models, proved that a moving craft met with far less resistance than commonly supposed, and likewise established the fact that the reactive forces of the water could be counted upon, in properly formed vessels at appropriate speeds, to greatly reduce or largely neutralize the seemingly immense resistance of the bow wave and its associate disturbances. His discoveries placed the art of designing ships and the accurate prognosis of the power required to drive them upon an entirely new plane. Since then experimental model basins or tanks of a far more pretentious nature have been established in nearly all of the principal maritime countries; and but for this vital aid to the designer it is safe to say that the modern Dreadnoughts and the latter-day great Atlantic liners would still be unattained.

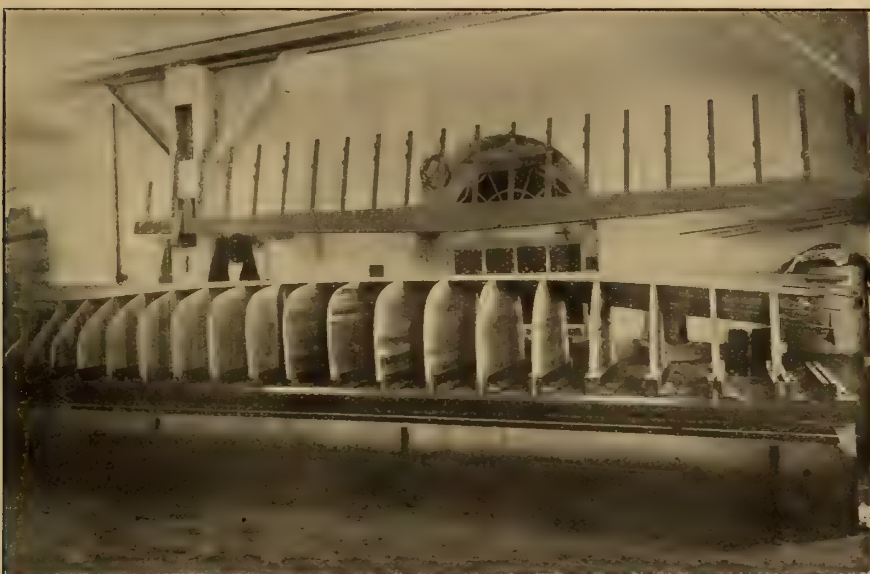
The primary objects of a model experimental basin are twofold: the first is to determine the best shape of hull for a vessel of fixed size and speed, and to ascertain how much engine power must be placed in her to realize within economical limits the best results; and the second object is to find out at what speed a craft of prescribed form can be most efficiently propelled, and, incidentally, to establish what motive power should be provided for that purpose. In one case, the investigator is free to change the shape of the under-water body of his craft, while in the second case he must take the vessel as he finds her and determine the maximum speed at which she can be driven without calling for a disproportionate expenditure of motive force. Despite the utmost skill of the designer, there is absolutely no other way by which this data can be reliably and precisely ascertained and the performance of a full-sized vessel predicted within the limits of variation now permitted by the state of the art and the sharpest sort of competition. It is a well-known fact that, as a ship approaches the critical speed peculiar to her particular form, every fraction of a knot's increase calls for a rapid increment of power, and beyond this critical speed any higher rate of travel is secured only by an extravagant and wasteful development of motive force, which is, for the larger part, absorbed in creating waves, while driving the vessel forward with but slightly better results. As this means not only adding to the

weight of the engines themselves, but likewise a very wasteful burning of coal, it is plain, in the name of efficiency and economy, that the vessel's speed should be made to conform more rationally with the physical limitations imposed by her form, or that form should be so modified as to make higher speeds possible with less horse-power and the consumption of fewer tons of fuel. Again, the evolution of novel craft to meet the calls of special service makes one of the most important demands upon the technical assistance of the model basin; and but for this aid to the designer, vessels of this sort could be evolved only by a studied and continued improving of a long list of like craft, bringing in its train heavy outlays and but slow attainment of the end desired, as England learned in her efforts to bring into being her torpedo-boat destroyers.

The "steam-line theory" enunciated many years ago by the fertile mathematical minds of Rankine and Lord Kelvin had for its foundation a "perfect" fluid, a frictionless substance, a theoretical concept, and until Froude came along this theory was the basis upon which calculations for ships' forms and the engine power needful to drive them were made. That the method was but a rough approximation was proved when the gradual abandonment of sail power called for greater operative ranges upon a given supply of coal. Water is not a perfect fluid, even though it follows closely in many particulars the imagined functions of the mathematical ideal; and it is in the actions of these imperfections—frictional resistances—that the crux of the problem lies. In a large body of any fluid there are tremendous latent forces, and the true problem is properly designing the form of a vessel and in determining the ship's appropriate speed is to disturb as little as possible the balance of these latent forces lest their immense power be developed in opposition to the moving craft. In effect, a ship moves between these self-adjusting forces like the equilibrist who stands in the centre of a see-saw weighted at both ends with large, freely-moving cannon balls, the least loss of balance being enough to make one or the other of the balls roll threateningly toward him.

Because of the frictional resistance offered by the water to the passage of a moving body, the problem becomes too complicated for mathematical determination *ab initio;* hence the peculiar value of the model experimental basin. To understand fully the gap scientifically filled by the basin, it may be well to review briefly the manner in which practical confirmation of its value was first obtained. In 1871 the British Admiralty had under consideration the building of a number of improved ships of war, and to facilitate matters the naval authorities instituted a committee on design, Dr. Froude being one of the members. The practical men on the committee were keenly alive to the difficulties of the task before them, and were well aware of the limitations peculiar to the mathematical methods then generally employed in approximating the speed possibilities of various ship-forms and the engine powers deemed needful to drive them. Prior to this Dr. Froude, in his own garden at Torquay, had carried on a series of private experiments of a practical character primarily free from all mathematical association. By towing thin planes covered with various coatings and also small models of different forms, Dr. Froude was able to establish facts of startling significance, and with this data as a basis he was able to work securely forward and then to attach to these discoveries true mathematical values. Dr. Froude's experiments showed him that the predetermination of the power required to drive a full-sized, self-propelled vessel was a problem essentially exterior to the ship and lay in discovering the measure of driving power lost

through wave-making and the development of skin friction and eddies against the wetted surface of the craft. By working from the outside inward to the propelling engines, Dr. Froude proved the puzzle open to practical solution; otherwise, as his predecessors had learned, to their sorrow and chagrin, the result might be an all too costly guess, even if dignified by an array of mathematical formulæ. He learned that every ship-form offered its own problems, and he discovered that every change self was no less important than the general discovery of the applicability of what is now variously termed "Froude's Law," or the "Law of Comparison." Dr. Froude freely laid before his government's officials the fruit of his private researches, and rationally urged that the Admiralty, as it had in contemplation the expenditure of large sums of money for new ships, should establish the practical value of his experiments by making certain towing tests with a full-sized craft, the



THE ERECTING TABLE UPON WHICH ARE REARED THE VARIOUS SECTIONS OF THE MODEL FORMER, SHOWING SOME OF THE PLIANT SHEATHING IN PLACE

of lines—slight though they might seem to be—made a difference in the resultant resistance opposed on the part of the water. Dr. Froude's investigations gave a new significance to Newton's law of similitude, and in its application to vessels showed that a small model of a full-sized ship reproduced on a reduced scale the identical peculiarities of a large craft of similar shape. His investigations further showed that, of the several components of the water's resistance, not all of these elements followed the same law. This in it-

"pull" on the tow rope to be accurately recorded by a dynamometer, which was, in effect, a sort of magnified spring scale, this "pull" naturally representing the true total resistance of the water that the vessel towed would have to overcome if she were self-propelled and running at similar speeds. The authorities assented, and H. M. S. *Greyhound* was the ship towed, while H. M. S. *Active* was assigned to do the towing and to carry the dynamometer indicating the drag or pull in pounds exerted by the towed *Greyhound*.

The trials, which extended over a period of about six weeks, brilliantly confirmed all that Dr. Froude had claimed, verifying with remarkable accuracy the independent tests made by him with a small model of the *Greyhound*. As a result, the British Admiralty took over Dr. Froude's private experimental plant, and there began a series of investigations that have revolutionized the art of ship designing, leading later to the establishment of larger basins not only by other governments, but by private shipyards and educational institutions. It is not generally known, but it is a fact, that the firm that built the *Lusitania* first constructed an experimental basin of its own in which to prove by private research just what could be promised for a full-sized craft which was to depart in so many particulars from anything previously constructed. Without the assurances thus obtained, it is not at all likely that the money involved in building that great vessel and her sister ship, the *Mauretania*, would have been ventured, nor could the British Admiralty have been given the promise of that extraordinary speed which meant the winning of a governmental subsidy quite vital to the business success of the undertaking.

History has a way of repeating itself. In 1891—twenty years after the British authorities recognized the value of Dr. Froude's methods, and when our navy was being considerably increased by a variety of types of vessels, each of which involved distinctive problems—the Chief Constructor asked Congress to appropriate sufficient money for an experimental basin.* Although this appeal was earnestly renewed each succeeding year, it was not until 1896 that Congress saw fit to provide money for this purpose. The average legislator thought the request only a cover for unwarranted expenditures, and seemed quite unable to grasp the relation between what he was pleased to term "a toy warship" and a full-sized craft capable of upholding the dignity of the flag. It was not until he was shown that a number of European governments already had similar establishments, and that we could never hope to take a leading position so long as we had to depend upon other people's data, that sufficient credence was aroused to carry through an initial appropriation for the United States Model Experimental Basin at the Navy Yard in Washington city. Even then there was skepticism; but figures have since shown the pre-eminently practical value of the plant; and each year's work gives added emphasis to its importance and to the vital part it plays in evolving vessels of increasingly superior qualities.

When we first began the construction of the New Navy every shipyard realized that the building of a man-o'-war involved a serious financial risk; in fact, one of the oldest and best of them was ruined through departmental severity; and in order to induce enterprise among these builders the Navy Department was led to offer bonuses for every fraction of a knot realized above the contract requirements, paying, in later instances, as much as $50,000 a quarter knot. To add to the likelihood of the shipyards reaping these rewards, the Navy Department, after making its preliminary calculations, cut down the official requirements, and thus gave the builders the benefit of a generous margin within which to work. This enabled the contractors to win substantial premiums, which need not have been promised had the Department been sure it was right and the contractors been fortified by figures previously determined by model-tank tests. The two million and more dollars paid out in this manner during the time speed premiums were in vogue would have been enough not only to pay

* Request first made in 1884 by the late Rear-Admiral E. Simpson, U. S. N., as president of the Naval Advisory Board.

for the building of the Model Experimental Basin, but to cover its running expenses for many years.

While the model hulls may be called miniatures of the full-sized proposed ship, still the small vessels are fairly large affairs. In most experimental basins the models are fashioned of paraffin, which can be remelted and used over and over; but because of climatic conditions it is quite impossible to use this material at the basin in Washington. The models tested there are made of white pine, which, while somewhat more expensive, has the advantages of greater strength, and is not prone to change form as are those of paraffin. Abroad, paraffin models are made—even then with considerable risk of deformation—in lengths ranging from 12 to 14 feet. At Washington the wooden models are made safely 20 feet long. This increase in size is of the utmost advantage, because it gives larger and more positive figures, and thus aids the investigator materially in bridging the gap between the functioning of the model and the probable performances of the full-sized craft—a bridging which, to some measure, must be a matter of judgment based upon experience and the tabulated data on hand. The significance of the larger model can be better understood by taking, for example, a proposed ocean liner 720 feet long and to make a maximum speed of 24 knots an hour. By "Froude's Law," the model's ratio of displacement, compared with that of the proposed liner, is as 1 is to 46,656 for a 20-foot model, and at 4 knots—the corresponding speed for the model—the model's resistance will probably be less than 40 pounds. On the other hand, with a 12-foot model, the relation of the model to the proposed liner would be as 1 is to 216,000, the model would be towed at a speed of 3.09 knots, and the recorded resistance would probably be less than one-third of that for the 20-foot

THE FINISHED FORM OF A FORMER-MODEL, SHOWING THE MANNER IN WHICH THE FLEXIBLE ROUND MOLDING IS ATTACHED

model. All errors due to mistakes in reading decimal parts of this smaller resistance would be correspondingly magnified by the ratio factor which becomes the multiplier in determining the application of the model's data to that of the large vessel. The use of 20-foot models, therefore, makes for accuracy, increases the value of the figures thus obtained, reduces the gap between model and ship, and leaves less to rest upon the shoulders of the investigator in determining how this small total model resistance must be separated into its three prime components, only two of which follow the "Law of Comparison," while the third must be evaluated by a different method.

The total resistance encountered by a vessel in motion is threefold in its composition; and, taken in the order of their normal importance, they are "skin friction," or the clinging and checking tendency exerted by the water upon the surface of the under-body of a craft, resistance due to the formation of waves, and especially those waves that sweep away diagonally from the vessel without any beneficial reaction, and last, the resistance that results from eddies which disturb the normal flow of the theoretical "stream-lines" and thus further upset the balance of the reaction. In addition to this, there is the resistance due to the action of the propeller in motion; but this is commonly included in the factor of eddy making, and in properly designed vessels this is not a serious percentage of the total resistance. In ships of ordinary form and at moderate speeds the "skin friction" constitutes sometimes as much as 90 per cent. of the total resistance, while at higher speeds the "skin friction" ratio is decreased and the resistance due to eddies and wave-making grows more important. At still higher speeds, where the vessel is traveling at the critical limit due to her form—such as that now made by fast torpedo craft and "scouts"—the percentage of resistance due to waves and eddies may even exceed that resulting from "skin friction." The problem that must first be solved by the tank is that of properly separating these frictional factors into two main groups, namely, the "skin friction factor" and the "residuary resistance factor," this latter embracing not only the resistance due to waves and eddies, but also the disturbance of the "stream-line" balance occasioned by the action of the moving propellers. The "residuary resistance" follows Froude's "Law of Comparison," and in order to determine its value the model is absolutely necessary. The "skin friction resistance," on the other hand, is not amenable to the same law, and is not influenced by the form of the underbody of the ship, but is governed, instead, by the area of the wetted surface and the relative smoothness of that skin, and by its length, irrespective of its shape. This was one of Froude's most remarkable discoveries. The total resistance of the model as recorded by the dynamometer on the towing carriage minus the "skin friction resistance"—determined by towing at like speeds thin planes of wetted area, length and surface similar to that of the miniature ship—yields the "residuary resistance," which can be modified only by changing the form of the under-body of the vessel. As experimental data accumulate, experience shows, in a general way, how changes of form can be made and the broad results prophesied; but in dealing with novel types or with ships that must be of unusual performance, precision of prediction can be secured only by the most careful and systematic testing of a succession of models, and failure is thus avoided by a modest outlay of only a few hundreds of dollars. It is a work of this sort especially that the Basin proves of the utmost value.

When the preliminary plans were preparing for our vessels of the "scout" class—the *Birmingham, Ches-*

ter and *Salem*—one of the greatest experts on the form or "lines" of ships was detailed to develop by eye and his highly-trained natural gift the body form for those vessels. At the same time, independent efforts were made by means of a number of models to arrive at the best results; but when the comparative figures were finally tabulated it was found that better speed and a smaller propulsive effort could be secured from boats built after the designs worked out by the Basin rather than from the "lines" developed by personal skill alone. In investigating the matter, it was discovered that a vessel of 4,000 tons displacement and 350 feet long required—in order to make 26 knots—more than double the horse-power of a vessel of the same weight or displacement, but made narrower and shallower and lengthened 100 feet. The military and the economic advantages upon a given coal supply resulting from this discovery should be sufficiently apparent to call for no comment. As the Chief Constructor has publicly stated, "There is absolutely no method known by which such information can be obtained except through the Model Basin; and, without it, the Bureau would be working largely in the dark concerning the majority of the problems of resistance and propulsion which require solution in the course of its work."

The character of our coast lines, especially that of the Atlantic seaboard, and the relatively moderate depths of water leading into some of our most important seaports, have made it imperative that our heaviest and largest battleships should be modeled with particular regard to these geographical limitations—conditions that do not generally exist abroad or influence the designing of foreign ships of the line. Accordingly, from the beginning of the building of our battleships we have been forced to change the underwater shapes of our vessels to meet

THE FIRST MAKE-UP OF THE WOODEN MASS FROM WHICH A MODEL IS CUT BY THE MODEL-FORMING MACHINE

the conditions of local circumstances; and, therefore, we have been placed in a position where it was practically impossible or inadvisable to attempt to use with any satisfaction the data to be gathered from the performances of ships of similar displacements but of different form abroad.

The course pursued in preparing the "lines" for a trial model and the actual construction of that miniature model 20 feet long and of identical shape. Cross-sections of the vessel's body at regular intervals are thus reproduced on stiff paper, and from these patterns thin wooden sections are sawed. These sections are erected at their proper distances from one another upon an iron table and there covered with pliant strips of wood, circular in section, which give to the structure the form of the desired ves-

THE MODEL CUTTING MACHINE

The lower model is the former, and the contact wheel is shown projecting between the two operators. The upper is the mass of glued planks which is being roughed into shape by the cutting saw on the end of the projecting arm—this arm being connected by a link with the lower one terminating with the contact wheel, and in this manner similar motion is translated to the cutting saw.

craft is not without its measure of interest. All of these small ships, without regard to the size of the proposed vessel, are made of a uniform length of 20 feet. The plans of all United States naval vessels are commonly drawn to a scale of a quarter of an inch to the foot, and by means of an eidograph—a pantographic instrument—it is possible to translate or transcribe the proportions of the original plans so that they shall conform to those of a

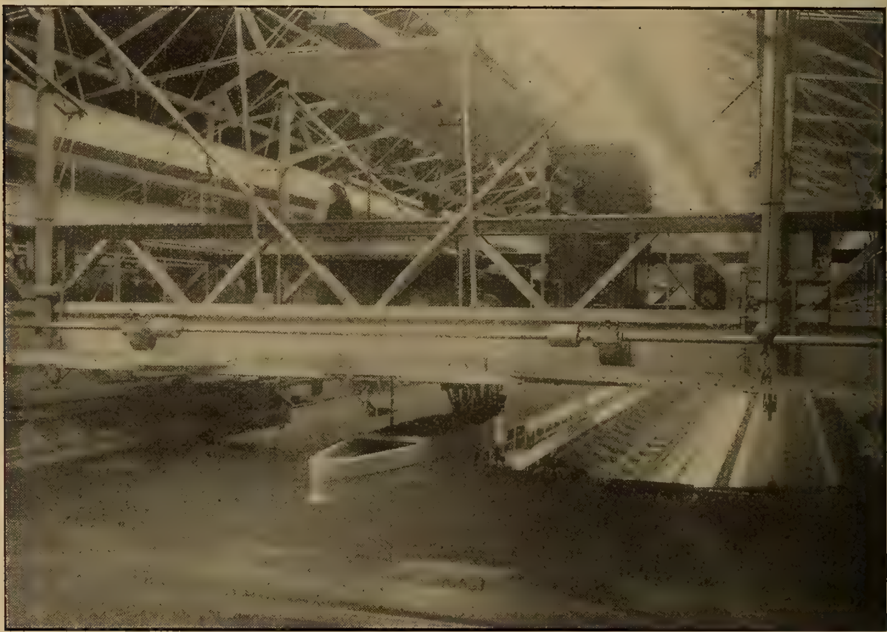
sel, but about a half inch greater fullness than the body of the ultimate model. This is known as the "former." While this is building the material for the true model is being massed, and consists of pine planking firmly cemented together, under pressure, by means of waterproof glue, hollowed out, and roughly of the general character in length and breadth of the proposed miniature, as illustrated on page 609. The "former" and this rough of the true model are now

placed in the cutting machine, as shown on page 610, the "former" occupying the lower platform and the rough of the model the upper one adjacent to the cutting saw. The operator guides a rolling tracer over the body of the "former," and the saw on the other end of the balanced arm cuts away the rough material to within a fraction of an inch of the desired dimensions. After this the "former" is smoothed by having the interstices between the round withes filled with plaster of paris, rotary cutters are substituted for the saws, and the model is given a fairly uniform surface. It is then taken from the machine, and the ends, which are not cut mechanically, are modeled by hand; and finally, sanded discs, electrically driven at high speed, produce a well-finished, smooth surface, true to the desired dimensions. The model is next painted inside and out, rubbed smooth by hand, and then completed by a coating of specially prepared varnish. Prior to these concluding touches, the shaft struts, bilge keels and other kindred features are attached. Careful measurements are now taken from the model to see that it faithfully reproduces the "lines" previously drawn, and, with this fact established, all subsequent dimensions are taken directly from the model and calculations made alone therefrom.

The model is now ready to be carried to the Basin for testing; but before it is attached to the towing carriage and given its speed trials, it is put in the balancing tank and carefully weighted with bags of shot to correspond to the desired displacement of the full-sized craft. This operation being completed, the small vessel is then attached to the arm of the towing mechanism of the carriage, as indicated in the illustration. This arm, in effect, is worked on the principle of a spring balance, the resistance or "pull" being indicated in pounds upon a recording cylinder when the carriage is in motion. The

THE FINISHED MODEL IS HERE SHOWN IN THE BALANCING TANK, AND IS BEING LOADED WITH BAGS OF SHOT TO THE DESIRED DISPLACEMENT WITHOUT DIRECT REGARD TO DRAFT

towing carriage is driven by electric motors, so arranged that they provide for the nicest regulation of speed and uniformity of motion. The actual speed of the carriage is checked positively by electric contacts made at fixed intervals along the track, tallied by means of chronographic records; and the three elements of distance, time and pounds of resistance are simultaneously marked upon the run sheet. Each model is run a number of times and at progressive speeds, which extend from the lowest rate of travel for the probable ship up to a speed considerably in excess of that desired. Curves are plotted from this data which give a perfect record of the speed and power possibilities of a full-sized vessel built from similar lines. Should these curves show undesirable resistance, and accordingly a heavy demand for propulsive power at certain speeds, the experts at the Basin then decide whether the model shall be modified and how, experience and the accumulated data on hand being drawn upon to suggest the direction in which changes shall be made. This modified model is then tried and the results tabulated, as before, until records are secured giving promise of the desired condition. As has already been said, the total resistance thus recorded represents the opposition which must be overcome by the thrust or drive of the ship's propellers in forcing the craft ahead—in other words, the effective horse-power exerted by the screws. This is not the indicated horse-power actually developed in the cylinders of the motive engine, but is that power minus the force lost in overcoming the inertia and friction of various parts of the machinery, as well as the "slip" or ineffective part of the propellers' action. The effective horse-power—that registered by the dynamometer of the towing carriage—in well-designed ships with good engines and proper propellers is between 50 and 60 per cent. of the total indicated horse-power. It will thus be seen that, in order to apply the results of the Model Basin tests,



SHOWING THE MODEL IN THE TOWING BASIN AND ATTACHED TO THE TOWING CARRIAGE FOR A RUN

THE RECORDING MECHANISM OF THE TOWING CARRIAGE IN THE TANK AT THE NAVY YARD, WASHINGTON, D. C. SWITCHBOARD ON THE RIGHT, AND THE MOTORMAN IS STANDING WITH HIS RIGHT HAND ON THE CONTROLLER

a proper design of propeller should first be worked out, and then the line of calculation carried inboard through the various moving parts right up to the cylinders of the engines, that are the ultimate index of the horse-power developed.

With the total resistance of the

model secured at the various speeds, the next operation, in order to make this data applicable to a full-sized ship, is to determine the "skin-friction factor," which does not follow Froude's "Law of Comparison." Accordingly, a thin plane, painted exactly like the model, so that its surface corresponds, of similar length, and of wetted area equal to that of the under-water body, is next towed at the several speeds previously recorded of the model, and the results are then deducted from the total resistances indicated at the same speeds for the model. The remainder in each case indicates the "residuary resistance factor," which does follow Froude's "Law of Comparison." In determining the skin friction for a full-sized ship the data secured by towing the thin plane is multiplied by something less than the square of the speed of the intended ship, i. e., by the 1.83 power, and then increased directly by the multiple of the actual wetted area of the under-body of the ship.

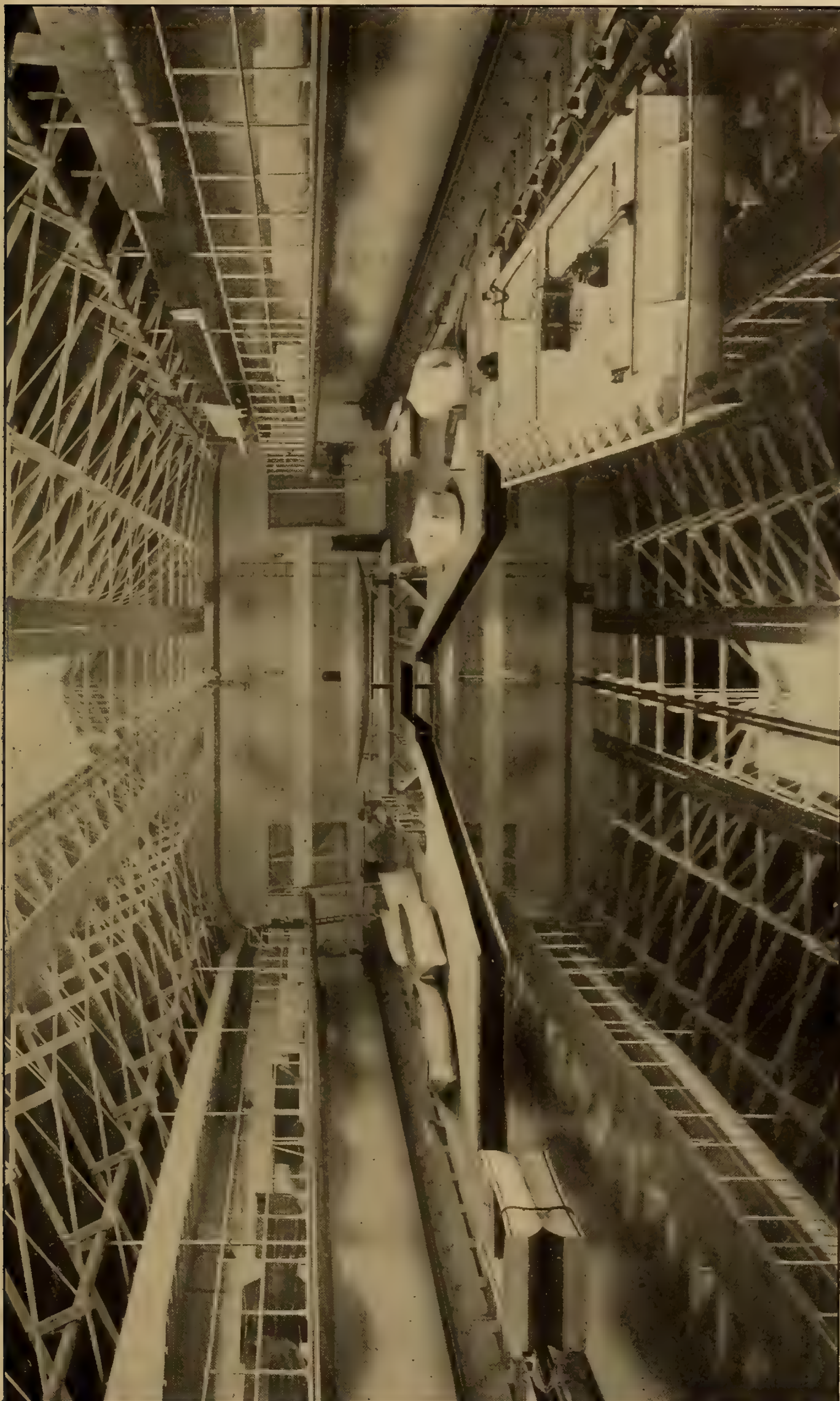
The coefficient of friction of a smooth plane surface in water varies with its length, and the factor 1.83 is the result of experiments made years ago with planes of various surfaces and lengths both by Dr. Tideman and Mr. R. E. Froude, the son of the pioneer in this work. It is not unlikely that there is urgent need for experiments with planes of far greater length than any yet tried, and tests of that sort would, in all probability, affect the values of both Froude's and Tideman's tables. The importance of this can easily be recognized when it is remembered that, with ordinary vessels and moderate speeds, the "skin friction factor" ranges anywhere from 80 per cent. to 90 per cent. of the total resistance encountered.

Model basin tests are made in fresh water, and to make the figures therein obtained applicable for sea-going craft, these results must be multiplied by the difference in density between fresh water and that of the ocean, which is generally taken as 0.026 greater.

Naturally, to the average layman all of this sounds more or less complex; but in the computing division of the United States Model Experimental Basin this work has been so systematized that the final figures are quickly obtained after the records are secured from the model runs. Each year's addition to the data thus obtained increases so much the facility and quickness with which novel problems can be met and much unnecessary preliminary experimenting avoided.

The illustration on the opposite page shows one end of the model basin. The balancing tank and the pit around it, in which the models are ballasted preliminary to towing, can be clearly seen. This pit is just forward of the cigar-shaped model of a submarine, and above this model is a friction plane by which the skin-friction factor of one of the models was determined. In the near right-hand corner, floating, is the skimmer, used for removing the scum and other accumulations from the surface of the water. The gallery along both sides of the tank is used for the stowage of models.

The cost of preparing trial models for a single type of vessel and testing them probably does not exceed a thousand dollars at the outside under circumstances involving a large number of tests and the making of a number of models. As these experiments permit the designer to predict with great precision the possible performance of a ship ultimately costing ten or twelve millions of dollars and remove all speculation as to the vessel's probable efficiency, the economical value of this modest preliminary outlay speaks for itself. Under the best of conditions prior to the establishment of model tanks, there used to be a very serious measure of doubt involved regarding a craft's prospective functioning whenever that vessel embodied departures from previously built ships. Besides the ex-



THE WASHINGTON TESTING TANK. VIEW OF ONE END, SHOWING SUBMARINE AND OTHER MODELS

ample given of the experience gained in planning the body form for the "scouts," there are on record numerous instances where shapes of hull—which to the practical eye suggested the likelihood of the best results—were proved by the model basin to be far from desirable. When the first of our torpedo-boat destroyers—built after the Navy Department's designs—were given their speed trials the results were disappointing. The builders believed the lack of speed to be due to the shape of the boats, and several of them wished to make extensive alterations in the vessels' forms, which would have involved an outlay in each case of between $30,000 and $40,000. This speculative bubble was quickly pricked by the results of a few experiments made at the United States Model Experimental Basin, which showed that still better performances than those sought by the builders could be obtained by making only slight changes, involving on an average but $2,500. The tests in the Model Basin showed that in some cases the difficulty was not with the form of the boat, but with the character of the propellers fitted to her.

THE MARKING FRAME IN WHICH THE WATER LINES ARE DRAWN ON THE FINISHED MODEL. THE PENCIL-YOKE IS DRIVEN BY A SMALL ELECTRIC MOTOR UNDER THE BED AT THE RIGHT-HAND END

In his annual report two years ago, the Chief Constructor gave some interesting figures regarding the further practical value of the Basin. He said: "While it is difficult and hardly appropriate to judge by financial standings work which is largely of a scientific nature, it is unquestionable that during the past fiscal year, as in former years, this establishment has amply justified its existence and maintenance, and has made a return to the Department of much greater equivalent value than its cost. The cost of maintenance, and the making and testing of models for the Bureau, was, for the year, less than $25,000. Investigations with relation to the underwater form of the *South Carolina* class and the new destroyers, which were undertaken and largely developed during the year, would alone more than justify the total expenditure for maintenance of the tank, although the cost of these investigations was only a small part of the total work performed, and the entire cost of maintenance of the tank was less than one-third of one percent. of the total cost of a single battleship. The finally accepted model of the *South*

Carolina and *Michigan* will result in a gain of speed for those vessels under trial conditions, due to improved under-water form, of about one-half a knot, as compared with preceding vessels of the same size, whose lines were developed in the earlier stages of work at the Model Basin, and were themselves much superior to the lines of still earlier battleships which were designed before experimental work in the Model Basin was practicable.

A FINISHED MODEL WITH SHAFTING AND PROPELLER STRUTS, BILGE KEELS, ETC., ATTACHED. THE VARIOUS WATER-LINES ARE INDICATED BY THE DASHES AT VARIOUS SECTIONS

"For our earlier battleships, for which speed premiums were provided, the rate of premium was $25,000 for each increase of one-fourth of a knot. If this were applied to the *South Carolina* and *Michigan,* it would amount to about $100,000 for the two vessels. From careful and systematic experiments made during the year, the Bureau will be able to adopt for the new destroyers a type of after body which will practically permit the speed of the flat-stern type to be maintained, but will result in distinctly superior sea-going qualities, the flat-stern type not being well adapted to rough water. Hitherto the flat stern has been regarded as essential to high speed, and was therefore adopted for vessels of the destroyer type. Three vessels of the destroyer type were authorized by the last naval appropriation bill at a total cost for hull and machinery of $750,000 each. On the conservative assumption that, with their improved sea-going capabilities, they will be only 1 per cent. more valuable than similar vessels previously designed, the Department will gain in these three vessels an increase in efficiency equivalent to the total sum expended during the year for the entire work of the Experimental Model Basin."

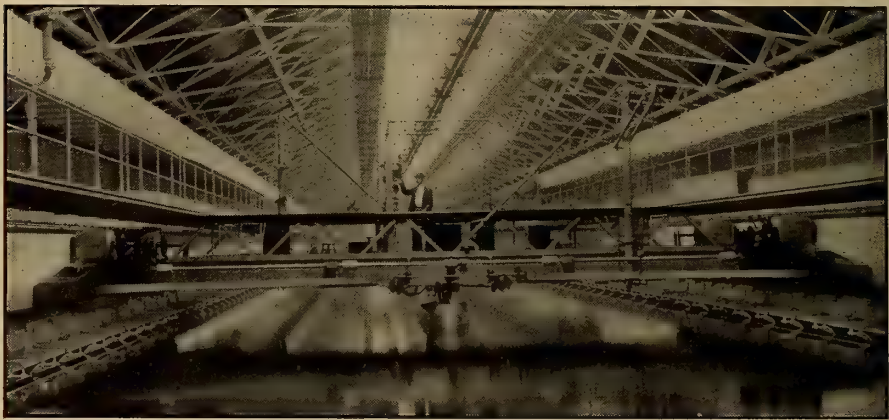
The battleship *New Hampshire*—authorized the year before the *South Carolina*—to which the Chief Constructor's remarks refer, on her official acceptance trial made 18.5 knots when developing a total indicated

horse-power of 20,000. According to the tests in the Basin, the *South Carolina* is to attain the same speed upon a development of 16,500 indicated horse-power. The *New Hampshire* burned about 1.8 pounds of coal per hour per horse-power, and assuming that the *South Carolina* does the same thing, the latter vessel, with her bunkers filled with a like quantity of coal, will be able to steam at 18.5 knots about 570 miles further. This saving of 3,500 indicated horse-power—assuming a horse-power to be represented by 230 pounds of machinery—means that the newer ship can carry 359 tons more guns and amunition, or that her body may be defended by armour of greater extent and thickness, or that more coal can be stowed aboard, thus considerably increasing her radius of action without adding a pound more to her displacement. These are some of the material advantages resulting from relatively inexpensive model trials.

The number of models annually made and tested at the United States Model Experimental Basin has ranged from 100 to 150 during the seven full years of active work of the establishment. This, of course, includes also models of merchant vessels, private concerns finding it more and more to their advantage to make use of the facilities thus offered by the Government.

Apart from the directly practical work involved in determining the best forms for specific ships, as far as possible a part of each year's work is devoted to strictly scientific research of an important nature; and every month is bringing to light further insight into the refinements of the principles and the laws already accepted as well as discovering startling refutations of some of the older ideas regarding the actual motion of water in contact with a vessel's under-body. This work is directly under the supervision and inspiration of Naval Constructor D. W. Taylor, U. S. N., whose researches and papers upon subjects kindred to this work are recognized classics.

The press of practical work, however, necessarily limits seriously the employment of the government tank in research work of a purely scientific nature; but the country is fortunate in having at its disposal the model basin at the University of Michigan,



THE TOWING CARRIAGE WITH MODEL ATTACHED

The carriage is driven by four motors, one at each corner, and so geared that the motion is uniform and free from shock. The maximum speed at which the carriage can run is about 20 knots, but, of course, this is far in excess of model-towing requirements. The speed control of the carriage is by means of the Ward Leonard system. The carriage weighs in the neighborhood of 70,000 pounds.

PHOTOGRAPH, TAKEN UNDER THE TOWING CARRIAGE, SHOWING THE WAVE FORMATION OF A MODEL UNDER WAY

over which Professor Herbert C. Sadler presides. Professor Sadler devotes the better part of the active work of his tank to theoretical investigations, and the results secured have already proved of the utmost scientific and practical value. The many problems connected with the screw propeller are but yet very imperfectly solved, and extensive and very carefully conducted tests in model experimental basins will be needed before we are in possession of satisfactory information. It is not unlikely—in fact, suggestively probable—that each ship-form calls for its own peculiar type of screw, and the question of relative efficiency of the propeller, *per se,* can only be a rough approximate of the needs of the individual craft. In addition to investigations along this line, the development of the submarine has introduced a new factor in the art of naval warfare, and the model tank will make clear to us the circumstances under which vessels of this sort operate when running submerged. In this way alone can lines of further development be surely and safely predicted. Many of the laws and much of the data that will be thus secured will apply with equal significance to the problems of aerial navigation, modified, of course, by the different densities of the two mediums. In fact, one of the tanks in this country has already been engaged in making experiments in this latter field.

HYDRAULIC-POWER DEVELOPMENT ON THE PACIFIC COAST

THE PECULIAR CLIMATIC AND METEOROLOGICAL CONDITIONS ATTENDING THE UTILIZATION OF WATER-POWER IN CALIFORNIA

By Frederic A. C. Perrine

Each portion of the world has its own especial conditions under which its natural resources must be utilized, and in the general effort to harness the water-power of natural streams the engineer must consider the fundamental principles which cover the peculiar local relations. The present article, probably the last ever penned by the late Dr. Perrine, discusses in a singularly luminous manner the difficult problems involved in the utilization of the great water-power resources of California, in the light of a knowledge gained by a prolonged residence on the Pacific coast of the United States, reinforced by great engineering skill and powers of observation.—The Editor.

EVEN to the hydraulic engineer who is familiar with all of the important work done in the United States east of the Mississippi river, there is something startling in the water conditions to the west of the Sierras. At the first acquaintance of such a one with these conditions and the solutions of great problems presented to Californian engineers, he first shakes his head and looks grave, then ponders, and finally is happy in finding that he has at last come to a country where "rule of thumb" does not apply, and where only an engineer trained to understand the fundamentals of his problem can hope to succeed.

Perhaps in another generation the Californian engineer may have developed his own "rule of thumb"; but for the present, as in the past, he will startle the world with his accomplishments—not, as is often thought, by his lack of foresight and observance of good teaching, but because he has attacked new problems and offered solutions which will stand the test of time and service, while all the while offering something new for the consideration of his brethren. His work must necessarily be more nearly in accordance with the true properties of his materials than many engineers have been accustomed to work, for the simple reason that under Californian conditions the rough and expensively safe solution the engineering world is accustomed to use might be a means of completely killing many an enterprise requiring the aid of engineering skill.

These remarkable conditions demand detailed explanation, for it is true that to the west of the Sierras, as elsewhere, the rains and snows fall, the winds blow and the lightnings flash, and the elements, so called, are of the old, familiar type; also it is true that rivers run from the mountains to the sea, and that a waterfall can be utilized for water power, as elsewhere; but though all these things are so, it is still true that the order of such phenomena is different from that of any other country in which large engineering works never have been performed.

All the sciences of the earth and air are involved in the peculiarities of California water supply. The traveler to the West from the Atlantic coast passes over country alternately rising and falling, generally in moderate grades. He climbs the Alleghenys, where two locomotives with difficulty maintain the schedule, and descends gradually into

the valleys of the Ohio and the Mississippi at an elevation of about 725 feet, where begins an ascent of about 870 miles to Cheyenne, at 5,325 feet above the Mississippi. From that point begins the steep ascent of the Rockies, and in the next 33 miles the climb is 2,200 feet, and the Rockies are crossed at Sherman. From that point until California is reached the elevation is never less than 4,200 feet; but when the summit of the Sierras is reached and California entered, the grade falls in 100 miles from 7,015 feet to 60 feet, and we are in the great central valley of the State, through which flows those great power-producing rivers—the Feather, the Yuba, the American, the Tuolumne, the Mokolumne, the Stanislaus, the San Joaquin, the Kings and the Kern.

The Sierras, which we have described as descending at an average rate of 70 feet to the mile along the railway, form an eastern wall running from north to south in California, and ranging in height from 8,251 feet at the pass at Sherman to more than 14,000 feet in several of the highest peaks, forming a great meteorological barrier, storing the heat of the sun, precipitating the moisture from the air, and being the one most important element in the seasonal change which gives the interior of California three to four months of rainless and cloudless skies. Beyond the Sierras, to the west, lie the interior valleys of the State hedged in between the great mountains and the Monte Diablo range, while along the whole coast rises to about 2,500-3,000 feet the Coast Range. Beyond these mountains extends the Pacific, with its currents of hot and cold water, of which the most important is the warm Japanese current, similar to the Gulf Stream in the Atlantic.

Little is known of any of these rivers in the Pacific beyond their existence and probable location, though undoubtedly they combine with the Sierras in making the water-power problems of California original and difficult.

We may examine the effect of geological conditions on the meteorology of the State by a study of the records at the city of Sacramento, which is not only central in location, but represents in many ways the mean of the various local conditions which prevail over the whole area, lying, as it does, at the very foot of the Sierras, yet in the heart of the San Joaquin Valley and along the banks of the largest river flowing into the Pacific through the bay of San Francisco.

The records of that station have been kept since 1850, and show an annual rainfall of 19.41 inches, distributed as follows:

	Inches	Per Cent.
January	3.83	19.70
February	2.80	14.42
March	2.85	14.67
April	1.74	8.96
May	.80	4.12
June	.12	.62
July	.03	.155
August	.01	.051
September	.18	.93
October	.76	3.91
November	2.09	10.75
December	4.37	22.50

From these figures we notice the remarkable fact that since 1850 there has been almost no rainfall in August, and that during the four months of June, July, August and September combined the average rainfall has been only about 1¾ per cent. of the rainfall for the year.

Not only in manner but also in amount do the mountains of California control the rainfall, as may be seen from an examination of records over the entire State. In the north, where the mountains extend quite across the State, the total annual fall amounts to as much as 65 inches along the mountain tops; toward the valleys it gradually falls to a minimum of 15 inches in the northern valley and 10 inches in the southern. Beyond the Sierras, to the east, scarcely any rain falls during the entire year, and the region is desert, having an average fall as low as 5 inches over great amounts of territory. This holds true in the southern part of the State of Cali-

fornia itself below Tehachapi, where the Sierras bend to the west and join the Coast Range, forming the San Bernadino and San Jacinto ranges. Amidst these lower mountains of the south lie the citrus-growing country, skirting the Pacific; but behind them to the east is only desert—a desert of which the soil is fertile but devoid of water.

While the absence of precipitation for four months of the year accounts for the fact that only the mountains in the extreme northern part of the State are permanently snow-capped, yet snow falls heavily along the entire range, and it does not disappear until well into the summer season, gradually disappearing under the influence of the heated air rising up the cañons from the heated and parched valleys. While it lies and slowly melts the streams are kept flowing, so that the relation of the minimum to the annual flow of most of the rivers rising in the high Sierras does not greatly exceed that of many with which men of Eastern experience are familiar. The great difference lies in the fact that, while Eastern rivers are subject to sharp periodical freshets, against which provision must be made in dams and other hydraulic work, the freshet is almost absent in California, the rivers rising immensely in February, March, April and May, and dwindling to nothing in August and September.

This fact enables the engineer to approximate his storage more nearly to the total annual run-off from the drainage area than is generally possible in the East; it enables him safely to build high earthwork dams, which must never be topped by the water, and to rely upon the snows in the mountains more certainly as a storage reservoir.

But, almost overshadowing these meteorological facts, and in their influence on power development more striking to the casual observer, is the physical fact of the steepness of the mountains themselves. If we call to mind the fact that the railroad, seeking easy grades, falls almost 7,000 feet in 100 miles, we may, perhaps, realize the steepness of the water courses. The early miner saw and quickly caught the significance of these roaring rivers—torrents in character from head to the valley—and with ready wit harnessed and used them in his spectacular engineering.

All through these wild mountains the adventurous traveler will find, in lonely gulches and along bleak mountain sides and at the river beds, the ditches and flumes and dams used by these early engineers—some forgotten and gone to waste, but, as is even more surprising, many still in active use, although not always in the service of the miner.

In Eastern practice the fall of a rapid or waterfall is generally the limit of head available for a power plant; but the laws of the West have favoured the miner, and, through him, the hydraulic engineer, to the effect that the troublesome "riparian rights" of the abutters to the stream are inferior to "water rights," which give absolute ownership in the water itself for any purpose whatsoever—a right which is only subject to earlier rights of the same character and a continuous employment of the water claimed in a useful purpose.

At a "water right" the water may be diverted and carried at a level for greater head further down the stream or deflected altogether and used in irrigation or for city supply, according to the plan its owner may have formed.

Such a disregard of the old and much-venerated "riparian right" of the farmer and miller along the stream may appear unjust to one unfamiliar with California conditions, but when we remember the meteorological conditions already described the justice of this overturn of previous ideas begins to appear.

Were it not for rights of this character the great hydraulic mines would to-day be undeveloped; the fertile plains of the valleys would be

without their groves of peach, orange and lemon; no vineyards or olive groves would exist, nor would the scanty river-flow suffice for useful power development.

As it is, the mountains, with their heavy rainfall, furnish water to the arid plains and power to the cities. There is hardly a stream which, if followed to its source, will not reveal dams for impounding the water—away in the depths of the forest, where, but for such works and the rock piles left by the miners, one would be tempted to think no man had ever been before. A little lower down, but still far away from habitation, are the diverting dams at the heads of canals, or ditches, as they are called, and from these dams the ditches wind away along the mountain sides and across the gulches in flumes to distances of 20, 40, 80 or even 100 miles, where the last drop of the precious water is finally disposed of, some of it finding its way back to its own river, some into rivers in other valleys, and some of it into the juicy peach or orange, to be transported across the continent and consumed on our tables.

As has been said, these ditches were begun by the miners for the development of power to be used in their hydraulic mines and stamp mills. The great fall in the rivers and the length of the ditches brought about high head conditions, and the possibility of the high head made the hydraulic mine a possibility. Hydraulicking, as it is called, is but a method of handling large quantities of earth cheaply; when the miner developed beyond the pick and pan he used the "sluice," a trough with "riffles" or baffle pieces at intervals, holding mercury to catch the gold as the earth containing it was washed down the trough by a stream of water. In "ground sluicing" this earth was shoveled into the sluices; but when the high head became available the earth was torn out of the mountain and carried into the sluice boxes by a heavy water-stream of small volume but at great pressure, and in no other engineering work have great quantities of earth been handled more cheaply.

In this work a head of three or four hundred feet was used, and under this head a stream of 4 or 6 inches in diameter could be employed, not only to wash down the earth from a mountain side, but even to move and place rocks of more than a ton in weight. Perhaps, in hearing of these feats, the engineer imagines the mountain side undermined by the water and falling in a confused avalanche; but it is not so that the work is done. The water does undermine the hills and the avalanche follows, it is true; but this work must be done carefully or confusion would result. The quantity of earth moved at one time must be within the miner's ability to restrain and pass successfully through his sluice boxes. When the miniature avalanche has fallen the boulders must be picked up and thrown out of the way, the earth must be forced into its proper channel, and all of this is done by these wonderful streams of water.

For the mill, the wheel followed the hydraulic stream, and then began the use of higher heads and still more marvelous streams of water. The heads rose from three or four hundred to six, eight, ten, twelve, fourteen and even twenty hundred feet.

A paddle-wheel was used, against which the stream impinged, making the so-called "hurdy gurdy" wheel. On the Comstock this wheel was studied and improved, and dignified by the name of "impulse wheel." Under these great heads the wonders of the water stream were examined. At 1,400 feet, which is used in the plant of the Standard Electric Company, the free velocity is about 19,000 feet per minute, the pressure approximately 700 pounds. Such streams are apparently as hard as iron; no man can strike an iron bar through them; they will tear the skin from a man's hand; masonry melts before them like sugar, and

even in apparently clear water iron is rapidly worn away.

In one Californian plant in which the mistake was made of impinging such a stream at about an angle of 45 degrees on the bottom of the tail race, the owners tried to line the race successively with concrete, planking, water and boiler-iron; but in each case the rushing stream tore out the lining and hurled it away, nor was the difficulty overcome until chilled cast-iron plates 3 inches thick were set in the bottom of the race, and even these have had to be frequently renewed, being worn away in a comparatively short period of time.

Such forces, to be restrained, call for the highest engineering skill and the most careful workmanship, and no small amount of praise is due to the engineers who have successfully undertaken the control of such large amounts of water under such conditions.

In carrying out great hydraulic works in the East, account must be taken of the evaporation from the surface of watersheds and reservoirs in determining the available run-off from any territory under consideration; but in California the engineer must not only take into account evaporation in its relation to run-off and storage, but also he must preserve most carefully the precious water which has once been caught and stored in its journey from its reservoir to the power plant, and guard against evaporation and seepage in the construction of his ditches.

These ditches lead off from the rivers or lakes far back in the mountains, and as the beds of the rivers fall off rapidly toward the plains, the ditches soon find themselves well-nigh to the tops of the mountains, lined with the scant earth of their steep sides, or hanging in flumes along the cliffs, and later often pass straight through the thirsty earth of the desert.

In the plants of the south the perils to the precious stored water are extreme. Often the southern ditches run for many miles through country where the sands afford no secure bottom and where evaporation is as high as 5 inches per day of water surface. In such cases the exposed bottoms and surface must be reduced to the greatest possible extent. Where it is possible, the grade is increased to the practical limit of permanence of banks, and velocities of water are allowed beyond anything generally believed safe but still found to be reliable, though requiring constant watchfulness. In many cases miles of ditch are lined with cement or wood, and through the desert the water is led in large wood-stave pipes, and seepage through the bottom as well as evaporation from the surface almost entirely obviated.

For a wood-pipe construction, the wonderful *Sequoia Sempevirens,* or redwood, affords a material unexceled in all the necessary qualifications for such service, and miles of redwood stave pipe are used with well-merited confidence for structures which those not familiar with the conditions often ignorantly criticise as of a temporary nature.

The more striking points of peculiarity in the California water-power conditions have been here called to attention, but it must not be understood that the difficulties end with these; for, in fact, the engineer attempting such work must be prepared to solve original problems at every step.

There is little to guide one in solving the natural problems as they appear, as an engineer will well understand who has carefully read what has already been written; but, in addition, from the very first step when material is ordered until the work is completed there are problems to be solved as material is ordered, transported and placed. Manufacturers and workmen must be trained to an understanding of the problem and its solutions, and finally, after all is done and the plant in operation, a training in constant watchfulness must be begun. All day long the ditch-tender

patrols the banks of the canal, spade in hand, smoothing out the cause of a wrong ripple, clearing out twigs or grass, with ears alert for the little tinkle of water far down the gulch, indicative of a bottom leak. Night comes, and he sleeps within sound of some signal rigged ingeniously to sound "all's well" while the water flows, or to give an alarm for rise or fall. Indian tribes must be conciliated to care for the companies' interests at the headwaters, and all attending the plant must be trained to work, individually and collectively, for the care of that little stream of water flowing in a mountain ditch.

Stevenson, in his Life of Fleeming Jenkin, has said: "For what we may call private fame, there is no life like that of the engineer, who is a great man in out-of-the-way places, by the dockside or on the desert island or in populous ships, and remains quite unheard of in the coteries of London."

Never was a truer word said of the engineer's life. His friendships are amongst his fellows, and it is their commendation only he seeks, and sometimes even they do not appreciate his problems or his achievement; but nevertheless he builds his best, and whether it is a ditch in the desert or a dam on the mountain, his life's blood and heart-beats are in it, and no praise comes to him except from the work itself and the elements, which say to him, "You have conquered."

SOME SUGGESTIONS OF REFORM IN ENGINEERING PRACTICE

MANUFACTURING AND COMMERCIAL

By J. E. Livermore

WE have lately been passing through a serious depression in trade generally, the cause of which it is very difficult to locate; and it has occurred to me that when we have this slackness of trade we might well ask ourselves whether our methods in some branches of industry are not equally as bad as our trade. Is our system as good as it might be? If not, now is the time to look around for the leaks and ascertain what can be done to remedy them.

Bad trade invariably starts by making things bad for the workman, and the first step usually means a reduction of pay for the number of hours worked. Is this reduction carried out in the best possible way, and have we exhausted every other possible means of economy before taking this regrettable step? Methods of profit-sharing have been to the fore very much lately, and I believe that every scheme of that kind is worthy of consideration; I believe we still have large numbers of employers who dislike very much to cut down the wages of the workers. Conversation with the English workman on the question of cutting wages shows that opinions differ very much as to the best way of doing this. While the workman very naturally objects to it, one does not meet with many clear ideas as to proper methods of ascertaining when such a change is necessary or with any definite plan for carrying it out on the best system.

The American workman, however, holds very strong views on the wage-reduction question, and is inclined to look askance at English ways in the matter. I give his view of the question as nearly as I can remember in his own words. It is as follows:

"I sell to my employer my labour at a rate agreed upon. No fluctuation in the value of my labour should be caused by any change in the value of raw material; in fact, up to a certain point my value as a workman ought to increase as I gain in experience, because I can bring increased knowledge to bear on my work, and that increased knowledge should bring me increased power, which is worth dollars. There comes a slack time, however; orders do not come in fast enough to keep the works running, and we must ease up on expenses. This being decided upon, the works are put on short time; but if I get 25 cents an hour when trade is good, I expect to get the same when it is bad, only I shall work fewer hours. I have, however, extra time at my disposal, and I am not made to feel that my work is of less value than it was before the depression set in. There is a loss of business, and I must bear a proportion of that loss by taking a decreased aggregate wage resulting from working decreased hours. I run the risk of being shut out altogether, but so does the English workman.

"When I look at the English way, I find notices often sent out in various districts stating that after a certain date, which has been agreed upon, there will be a reduction of so much per week on day pay, with a corresponding reduction per cent. on piece-work rates. This, when looked at in cold blood, means to the workman that at one time he does a piece of work for, say, 40 shillings, whereas at another time he does the

same thing, uses the same tools, expends the same amount of labour, and works the same hours, but gets only 38 shillings."

This method the American regards as a direct invitation to kill time and as distinctly uneconomical. Human nature is weak; if you take 2 shillings off a man's pay per week without reducing his hours of work, he is very likely to make an effort to do 2 shillings' worth less work per week. Moreover, the working expenses are not reduced. There is no saving of power, light, and other incidental expenses connected with running the works.

If, however, we shorten the hours of work, we have a saving in these directions, too, while we do nothing to prevent a man from putting forth his best effort; and most certainly when trade is bad is the time when the best effort is needed. The question does not end here. As trade revives, the workman naturally asks to have his pay increased again; but often there are things only known to those in authority which make this impossible. Then rumours of a strike are heard, and you have an industrial dispute in the making. This favourite measure of economy is particularly to the front in England, and seems to be a fruitful source of trouble. Economy that begins by cutting down a man's pay is not likely to be of a satisfactory or lasting kind.

To interfere with the workman's weekly wage is like putting a match to gunpowder, and one cannot be surprised if trouble follows. In my opinion, the rate of workmen's pay is the last thing that should be touched, and even then with the greatest care. Labour charges are heavy, very heavy, and they must be carefully watched. When a reduction of pay is made it hits all the men, good, bad and indifferent; while if we have a method of more carefully sorting the wheat from the chaff much trouble can be avoided. Such is the opinion of the American workman, and it is not without interest. Although his arguments may be by no means flawless, there is much in them to afford food for reflection.

Some time back the North of England was in a state of unrest in the engineering and shipbuilding trades. Various sections of the different trades had a number of men on strike, yet all that resulted from it was a loss of trade, with a corresponding loss of wages to the workmen. At the end of a dispute of this kind a sort of truce is declared and part of the work begins again. The wages question is patched up, but the workman has one eye on his work and the other on his chief, while the chief has one eye on the men and the other on expenses. Neither man nor chief enjoys that sense of security which is the essence of smooth working, and the smallest trifle will start hostilities again. An atmosphere of this description hanging over the shop often prevents changes being made which would be better for both parties. A new rule is put into force, perhaps, for some reason or other, very suddenly. The men at first do not approve of it, and before they can test it fairly they lay down their tools and go out on strike. Would this have happened if a careful sounding of the men's opinion had been taken beforehand? Is it not possible to call together a number of men and discuss a proposed change in the works? There are little things which must be made plain; you must prepare the way for your change. It is not, of course, necessary to call together the heads of various trade societies for each little change you have to make, but I do believe that a little more round-table discussion would be an advantage. If that discussion is the means of improvement to both sides, then much good has been done, and that is true economy.

My next point concerns the method of taking the time on various jobs as they go through the shops. A great many workmen do not see this

question in a clear light, and it is a matter of regret that there is not a little more give-and-take honesty in dealing with it.

NAME		
DATE	TIME No.	HOURS

FIG. 1.—ORDINARY FORM OF TIME CARD

I am well aware that this is a thorny subject and one that is hard to get over. Looking backward I see myself one of a number reckoning up my time at the end of the day and putting it down on a form, as shown at Fig. 1. On the top of the form the clerk has written my name. In the first column I put the date, in the second I put the time number of the work I have been employed on, but at the third, where I put in the hours, I hesitate; "This job turned out well," I think to myself, "and it will bear a bit more time," or, maybe, "This was bad, it took longer, and if I put the full time down there will be awkward questions to answer." So I "fake" my time; in other words I try to make myself believe that the job which I spent 4 hours on was done in 3 hours. Now, what have I done? I have sent in a false statement of labour costs, for the timekeeper has copied my figures, and I have done my best to prevent my firm from getting at the true cost of that particular operation or part. Why have I done this? Simply because the true method of taking time has not been made plain to me. I have come to believe that I shall hear nothing further of the good job quickly done, whereas the bad job discovered by the office staff will bring down the foreman upon me. For that reason I do something to make a false return on what is a very vital matter.

Now suppose this time is recorded in another way. Fig. 2 shows a card which gives in detail practically all we want, and which can be used in every department. These cards are usually made in different colours, each denoting a certain department. They are made to fit in a small metal slip, and are hung upon a board which is placed in a convenient position in the shop.

Each morning the foreman's clerk looks over the cards to see that all time numbers are right, and the fore-

WORKMAN No.		DEPT.			
Date	Time No.	Part.	Hours		M/c. No.
			Man	M/c.	

FIG. 2.—IMPROVED FORM OF TIME CARD

man checks the time to see how his expenses are working out. Finally the timekeeper enters up the time on his books and prepares the labour statement for the cost clerk. Now a word about the card. This is printed exactly alike on both sides, as shown at Fig. 2. The foreman's clerk fills in the workman's name and his number, and writes in the name of the department in which the card is used. Where a department does say planing, milling, turning, etc., each of these will have a different colour of card to make sorting more rapid, and saves time in classifying.

Now we come to the workman's part. On the left-hand side he puts in the date in the form of figures, e.g., 3/7/8. In the second column he puts the time number of the job, in the third column he writes the name of the part, or the job he is doing, the fourth column is for the hours worked, and is divided as shown. In the first division of this column the workman puts the hours he has worked, in the second division he puts the hours the machine worked. If he runs two or three machines he must divide up his time between the machines. The machine which required most time and attention will claim that amount of time, not more, nor less. In the fifth column the workman puts the number of the machine.

To fill in this card is a very simple matter, but yet it has given much trouble, and many men unfortunately look at it as a trap on their time. Let it be known at once that whether a man is suitable can easily be found by observation of his methods, of the standard of his work, and by taking into consideration what he is doing, and what he is doing it with, etc. This time-taking is a vastly more important and far-reaching matter, and the entries should be made as true as possible, and every workman should be made to understand that a false entry willfully made means dismissal.

This time card is the foundation on which we must base labour charges of all kinds, whether making up cost or estimating for a second quantity of work. As I stated in the early part of this article, it is intended to prevent a man putting 3 hours to a job which really took 4 hours. Of course, something may have happened to a machine which caused it to stop for an hour; where such a thing happens the workman should write a note of it across the time card.

Now when it comes to taking the time, the timekeeper sees the hours the man has worked, and the hours the machine has worked, and he has also the number of the machine. He also has a book called the "idle machine" time book. When he sees that the man has worked 10 hours and that one machine has worked 9 hours, and another, say, 7 hours, he enters up in idle-machine time book for one machine 1 hour and for the other machine 3 hours; but why does he do this? Not to catch the workman, because, although one machine lost 3 hours it does not follow that this was due to the workman. The timekeeper enters it up for two very important reasons, which I will explain.

Firstly, every man knows that the time taken varies according to the character of the job, the kind of machine used and so on, the method followed, the tool equipment, the style and kinds of cutting tools used, the method of setting up the job, and the kind of material operated upon all make a difference. Suppose we are building a number of machines, and when we have made a certain number we find that on a given part our time cost always shows a certain amount of idle time, or, more correctly speaking, lost time.

In order to stop this loss we have to consider a fresh method of doing the work. We may, perhaps, introduce a jig, we may make special tools, and it is reasonable to suppose that by making these improve-

ments we shall prevent some of the lost time. We may set up the work more quickly, and make the operation easier for the workman. We have also the opportunity of considering whether or not the design of the piece can be changed. All these remedies must be thought of and applied. It is every business man's policy to make that particular article which he can sell and get the greatest profit on. If we jog along in the old style and let the workman arrange his time to suit himself instead of making an accurate return we are not likely to find out this loss until it has become a serious item. We have been thrown off our guard, and while we may have been able to make more of the articles which paid us best, we have probably done other work which did not pay so well. We have thrown them both together and lost a certain amount of money in the shape of lost time which, if discovered earlier, might have been prevented. It is like making £10 on one job, and losing £5 on another. This is one of the reasons why the time should be carefully taken; improvements can be made by taking careful notes and records, but this must be done in a systematic way.

The second reason is equally as important as the first. As this lost time is taken it should be carefully entered up, so as to show what amount of time has been lost on each machine every month. We want to know this because, when we buy the machine we invest a certain sum of money, and that machine must bring back the cash again. As it works in the shop we rate it as earning so much per hour while it is at work. The only money we get is from the product we manufacture and sell; to fix that selling price we must take into consideration the rate per hour of the machine, the value of the space it takes up, the interest on the money invested, the power required to drive it, and all incidental expenses connected with that machine. To bring in all these costs we must reckon up this lost time and spread its value over our finished products, so that each product bears a proportionate part of the loss. This may be done every month, or every two months, or at any time which may be found best, but if you fail to take your time properly how can you expect to get at this vital point? You only rob Peter to pay Paul.

These are the two chief things in connection with this time record, but the argument can be taken still further. You can tell from this lost time whether the plant and machines you are using are the best for your work. If, though you keep busy, your lost time increases on certain machines, you may be sure that your methods are not the best and you must seek improvements in the machines affected.

The time cards can be used for foundry, pattern shop, fitters, and also for draughtsmen, as the item "hours for machine" can be left out where not wanted. The principle they represent must be carried right through the works if they are to be effective. I believe that most readers who will consider these points fairly will think as I do, that the question of taking time as accurately as possible is a very important thing, and is one of the points that should always be insisted upon. It is just as much a necessity to know the time the machine is standing idle as it is to know the time it is working.

This question of time is only a part of one great whole, for it is always an advantage to have a number of records to look back at if they are carefully taken. Where a number of machines are built at a time, or only one machine, a clear record of the building should be at hand; and in this connection I will describe the "material stock and labour cost card," and the manufacturing sheet, two things which I personally have only seen in American

shops, though this does not imply that they are not in use elsewhere. The time taken to produce a given article is a very big question. We are always eager to get the best time on a machining operation, but it is well to remember that time extends beyond the actual period of machining, also time is often wasted in a reckless manner in processes other than machining. A lack of system and method entails endless expense and brought about by the improvements we have made from time to time. Fig. 3 is a copy of a "material, stock and labour cost card," which I have been privileged to examine. Of its merit I am fully convinced. When we see three such cards together showing records of three successive similar jobs we have brought out in the most unmistakable way what has been saved, owing to the improvements in methods introduced

No. MATERIAL & STOCK COST CARD

Time No. Date

Materials	Weight	Cost			Stock	Pieces	Weight	Cost		
I. Castings										
B. Castings										
S. Castings										
Mild Steel										
Tool Steel										
Total					Total					

FIG. 3.—A GOOD EXAMPLE OF A MATERIAL AND STOCK COST CARD

produces nothing but loss; it is the millstone that drags down the profits until they fall to zero. We have seen how the time card produces a record on various parts and helps us to form new ideas for further improvement. We will now describe how a second record is obtained.

If you produce machines either singly or in lots it is well to have a clear record of the costs, which can be turned up and referred to quickly, and which will show us the difference in the cost which has been during the period in question. Looking at the card "Fig. 3" we see at the top left-hand corner its serial number, and in a line with this is printed "material and stock cost card." Underneath is the time number, which will always identify the machine or piece to which the card refers; in a line with this is the word "Date:" here we write the date on which the work was commenced or the order issued. Under this we put the materials, their weight and cost, and the stock or

pieces with weight and cost. Under the column marked material we put such stuff as iron castings, steel castings, brass castings, tool steel, Babbitt metal, pattern material, and all such stuff connected with the machine, or lot of machines, the card refers to, and opposite each we put the total weight of each lot of material; opposite that, again, we put the cost. On the other half of this side under stock we put such things as screws, pins, nuts, washers, levers, hand wheels, and all such light stuff; opposite each we put the number of pieces used, their weight and their cost. This side of the card thus gives us a sort of bulk statement of the whole of the material that has been used, with a total cost, and separate costs for the various items.

We now come to the opposite side of the card, see "Fig. 4." This is numbered and has the same time number also; but instead of material we have the labour cost. Where the word "finished" is written we put the date on which the machine, or lot of machines, to which the card refers were completed. Under the word department we record the labour charges for each, and every department as they bear upon this job, from the drawing office down to the labourer who helps in the shop, and we put in the total value of the amount absorbed in labour for each department.

The card which I have just explained is, in fact, a part of the time and cost system, and is really a necessity. When you have made a machine, or a number of machines, and you go on reproducing the same class of machine, you have a record of all costs. Perhaps while making these machines you found that you could improve certain parts, and you did so; now, when the second lot is completed, you are able to make a comparison, and can see what saving your changes have effected; in fact, you have an absolutely plain statement which can be filed and referred to as occasion requires. You often hear a man say that he is doubtful whether some change he has made has paid him. If the record of that change had been carefully taken he would be

No.	LABOUR COST						
Time No.				Finished			
DEPARTMENT	AMOUNT			DEPARTMENT	AMOUNT		
Planing				Foundry			
Boring				Pattern Shop			
Turning							
Grinding							
Total				Total			

FIG. 4.—LABOUR COST CARD. TO ACCOMPANY THE MATERIAL AND STOCK COST CARD

able to say for certain whether it has paid or not. This card will enable him to compare the cost of material quickly; it will show by the labour cost what is the saving made in the department where the change took place. Against this he must put the charge of the expenses incurred in carrying out the change. These expenses, however, must not be put on to just one lot of machines; that would not be a fair charge; they must be charged as a separate cost and spread over all the machines affected; with an arrangement of this kind it should be possible to say beyond doubt what has been the gain.

The next form in connection with this time question is the manufacturing sheet, "Fig. 5," and, like the others, it must be accurately filled in and carefully filed for reference, otherwise it is of no value. On the left-hand corner of the sheet is a number for reference, also the time number dealing with the machines we are building. In the centre at the top are the words "manufacturing sheet," and in the right-hand corner the number of men employed on that particular lot of machines. In the first line we have the day of the month, the name of the month being inserted at the end of the line. Down the left-hand side, under the day of the month, we fill in the time particulars of the work under such heads as "order received," "drawings ordered," "drawings issued," "patterns ordered," "patterns finished." We have also the date of ordering the castings and forgings, with the date of their issue and the dates of all the machining operations. We get the date the planing was finished, also the milling, turning, grinding, etc., until the machine is inspected and ready to deliver.

On looking over this sheet it will be perfectly plain that we shall have a record of the whole of the time taken in building either one machine, or a number of machines, as the case may be. The tendency of present-day methods is to devote one's time to a certain line of machines, to standardize them, to make them as perfect as possible, and to produce them in such quantities as will give the best return for capital outlay. Suppose now we have built a batch of machines and in doing so we have, by means of our time-taking system, instituted a number of improvements in certain directions. We have by our method of cost reckoning found out exactly how much we expended to bring about these changes. Now when we come to make our second lot of machines we shall see by our material and labour cost card what we saved in our working expenses. With the manufacturing sheet we shall see what we saved in time, assuming that the numbers of men employed on the particular lot of machines are equal. These sheets must be kept as records; the information they give is useful.

But our manufacturing sheet gives us another advantage, which is this: The time given for the delivery of a machine tool or a piece of machinery of any kind is a very important factor, and in this respect many English firms are sadly deficient. They give a date, but very frequently overstep it, with sometimes serious results, which may mean the payment of a fine or the order being cancelled. This is not done intentionally, but is due, I believe, in many cases to not having any records of a reliable nature to refer to. Now it will be plain when we have completed one, or a number of machines, and have established some fixed data, that if we put in hand a second lot of machines and if, for example, a machine was sold on the day the castings were issued, then we ought to be able to give a certain date for the completion of the next similar machine, subject, of course, to there being no stoppage of work by strikes, or matters beyond our control. I believe that these points dealing with

time are of an incalculable value, and that the taking of time in this way cannot be neglected. These, then, are points to look at for real economy; the man who introduced these sheets has conferred a very great benefit upon the engineering trade.

While we are looking round for economy, suppose we pay a visit to the works stores and consider them in relation to the works. Is low first cost without a system the cheapest way to buy, or is it cheaper to have a system which helps us to buy at the right time? There is no doubt that a thorough system of keeping stock is a very necessary thing. While many firms can and do pay close attention to their stock, there are also many who do not; perhaps their works are small, and they think a first-class storekeeping system hardly necessary; this I believe to be a mistake. If you have no proper means of finding out what materials you consume in a given time you can hardly expect to buy to the best advantage. You may be tempted to purchase more than you need, especially if the price is more favourable at the time. Now when indiscriminate buying is practiced it is that a little may perhaps be saved on the first cost, but after the purchase there may be a falling off of orders, and it may be found that so large a quantity was not needed. There is not the demand for the machine you are building, and you find that the stock of material is becoming a dead load, and is represented as so much capital tied up which would be more usefully employed in other ways. Maybe the price will fall before you can use this stock up. Then, again, you may have found it necessary to change your design, so that some of the stores you hold may be practically useless. If it could be possible to arrange for every firm to pay close attention to the stores and have a good system, the gain to all concerned would be a considerable advantage. It would tend to regulate both supply and demand. The stock should be purchased regularly and in methodical order, so as to make the demands regular.

In the first part of this article I have tried to show the advantage gained by keeping a close eye on time and cost charges, and also have attempted to describe a way of finding the exact time required to do the manufacturing work. Now if we succeed in this, we know exactly what stores we shall use in a given time, and from that we can fix our average quantity to buy, and we need not buy until we are quite ready. If we make the parts ourselves we shall know when to make them, and how many to make, and even if a boom sets in and we are a little out on our average quantity, that is no excuse for neglecting to exercise care at other times.

In considering this question of buying stores for our works, let us imagine a point at our left hand, then a space, and a point at our right hand. We will assume the left-hand point to be the place where we receive our raw materials and such stock as we require for producing our machine. In the space let us imagine our works where this material is worked up into the machines we are building. At the point at our right let us suppose the finished article leaves the works. Now by a careful arrangement of a few details we can buy our stock so that it is kept flowing through our works. We want it to arrive just at the right time, but unless we are careful to note just at what rate the finished article is leaving we cannot properly direct the ingress of raw material. Our system of buying must be such that as soon as there are signs of the finished articles being arrested, we must also arrest the raw material; if not there is a choke and loss takes place. That loss is in the form of capital locked up in the stock, which we did not take pains to stop in time. Over-production is a serious matter, and steps to pre-

No.

Time No.

MANUFACTURING SHEET

No. of Men employed.

	Day of month.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	MONTH
	Order Recd.																																
	Drawing Ord.																																
	Drawing Issd.																																
	Patts. Ord.																																
	Patts. Fins.																																
Ordered	I. Castings																																
	B. "																																
	Forgings																																
Issued	I. Castings																																
	B. "																																
	S. "																																
	M. "																																
	Forgings																																
	Small parts																																
Progress of operations	Planing																																
	Boring																																
	Milling																																
	Turning																																
	Drilling																																
	Gear Cutg.																																
	Grinding																																
	Erected																																
	Painted																																
	Inspected																																
	Ready to deliver.																																

FIG. 5.—THE MANUFACTURING SHEET. A COMPLETE RECORD OF THE TIME TAKEN IN BUILDING EITHER ONE OR A NUMBER OF MACHINES

vent it are worthy of close attention.

A simple plan of buying can be arranged as follows, and will, I think, be found a great assistance. Suppose we use the card index system, and have a pilot card ruled as shown at Fig. 6, with a series of cards behind it, but without the letter B. Underneath this we put the word stock and opposite it the articles the card refers to. Underneath this we divide the card into four parts: in one we put the word "received," in the next we put the word "issued," in the third we put the words "on hand," and the fourth "monthly average." The first part headed "received" is divided up again under date, quantity, cost; the part headed "issued" is divided under date and quantity only.

All materials, stock, etc., which we buy are placed in the stores. The storekeeper checks the invoice and enters on the card under "received" the date on which the stores arrived, the quantity of them and the cost. This latter item, however, may be inserted or omitted at the discretion of the management; while some firms leave out the cost, others put it in for complete reference. On the opposite side we put the date when these stores are issued to the works and the amount of them. Now if we look at the card we notice a letter in the top left-hand corner, which denotes that all stores, or stock with names beginning with B, have a pilot card with the letter B on it, and immediately beside this letter we write the name of the stock. When this card is full we put in a new group card, which is ruled in the same way as the pilot card, but without the letter B. The old cards when filled can be destroyed, because we have a permanent record of stuff used as shown on our remaining cards, which will always be up to date. It will be seen by this that to keep a close record of our stock is a fairly easy matter. There are no costly books, and our cabinet is always quick and handy. We shall also quickly find the average amount of stock that we use in a given time, which will enable us to buy at the right time, and by subtracting the "issued" from the "received" we know exactly the quantity we have on

B

STOCK

RECEIVED					ISSUED		ON HAND	MONTHLY AVERAGE.
Date	Quantity	Cost			Date	Quantity		

FIG. 6.—TYPE OF CARD WHICH IS A LABOUR AND TIME SAVER FOR BUYING AND STOCKTAKING

hand. This amount is written down in the third column of the card under "on hand." Having found out our average quantity consumed, say per month, we enter this up in the last column of the card marked "monthly average," and this average is intended to be a guide to the quantity we shall require to buy from time to time. If every kind of consumable stock is reckoned in this way, the saving of time will be very great, even if only in connection with stocktaking. It does not matter whether you buy goods by measure, weight, or numbers, the record is clear, and you can sit at your desk and take stock more quickly, easily and exactly than by turning the place upside down and making general confusion. On these points I claim we can expect real economy. The advantage of a system of this kind is that at a slight expense it can be used in all kinds of small shops, and its value is as great there as it would be in a large manufacturing plant.

(To be continued.)

Current Topics

STEAM and electrical engineers have to deal with machinery of a very simple order. In electrical machinery the chief complexity appears to be with the static portions, such as the switchboard connections. It is when we come to look into textile machinery that we realize what complexity may attain to. The early cotton machinery inventors, such as Arkwright, Hargreaves, Crompton and Kay, were men of genius in devising the methods of dealing with cotton fibre; but the crown of their efforts was put on by Richard Roberts in perfecting the self-acting mule spinning frame.

In this machine the fibre to be spun is delivered in a soft, untwisted bundle, or string of fibres, from between rollers. This fibre is attached to a rapidly rotating spindle, which from a position close up to the rollers retires to a distance of about 60 inches at a speed somewhat greater than that at which the rollers rotate. The newly-formed thread, still only partially twisted, is not broken by this tension. It is a peculiar property of twisted fibres that the twist runs to the thinnest places and leaves the thicker parts soft, less twisted and less strong, and the result of the few inches of stretch in each draw of 60 inches is to draw all thick portions thin. As they thin down and would break, they are as rapidly made strong by the twist which runs into them.

In a modern mule spinning-frame there are many hundred spindles, all doing the same work and carried in bearings on a moving carriage. When the carriage has reached its full travel it stops and the spindles continue to rotate and add the total twist to the yarn necessary to render it sufficiently hard and strong. At this point the spindles all come to rest and turn backwards a few turns for backing off the helically-wound length of yarn extending from the cop, or portion already wound on the spindle up to the nose or point of the spindle. Backing off done, a horizontal wire descends and presses each thread down to the right point, and the spindles again rotate and wind up the yarn exactly as quickly as the carriage moves back towards the rollers, with something additional, namely, about 3 inches extra, which is represented by one turn of the rollers performed while the carriage runs in, this one turn adding about 5 per cent. to the output and using

time otherwise occupied in running back and winding only. There is an early limit to the speed of running back, so that the extra 3 inches of winding is all gain. The little shape of wound yarn on the spindle is taper on the part where successive layers are wound, so that there must be a steady variation between the speed of the carriage and the winding revolutions of the spindle. All this is provided for, and the spinning mule to-day is certainly one of the most complicated bits of scientific mechanism in use, and it is of Richard Roberts's perfecting. Not merely must the machine perform all these duties, but it is further so arranged that the change of a wheel or two and a rope rim pulley will make it right for performing equally well the same duty in spinning threads finer or coarser. Though a self-acting mule may be 130 feet long, the whole of its many hundred spindles move as one, and, with the exception of a few small wheels and scrolls for roller driving and carriage parallel movement, all the complicated mechanism of the mule is concentrated in a headstock placed mid-length of the machine.

To understand the action of this headstock demands days of careful watching, and is in itself a liberal education in mechanism. Toothed wheels, rim-band wheels, scrolls, copying rails, cams, clutches and link gear are combined to form the harmonious whole of Roberts's self-actor. After him it was easy for other inventors to modify, and modifications of no doubtful value have been made. But the Roberts mule has never been displaced. Roberts patented his mule only in the year 1832, and by 1834 it had already been applied to over 400,000 spindles in sixty factories, showing that in those days a new invention, if good, did not go long a-begging and men knew a good invention when they saw it, which is more than can be said of many of the so-called leaders of industry to-day. Previous to Roberts, the actual inventor of the mule was Crompton, of Bolton; but Crompton's mule was very partially power-driven. The spindles were rotated by power when spinning; but the winding on of the freshly spun length of yarn was done by hand, and the faller wire, which guided the yarn upon the right part of the spindle and cop, was hand-controlled, and Crompton's mule possessed only about fifty spindles, if so many. The mere winding of the yarn upon the cop calls for a good deal of mechanism, for the winding must not be straight and parallel, as on a spool or bobbin: it requires to be slanting on the top and run up and down, so as to bind the cop into a firm, solid bundle of yarn that will not easily break across or pull apart, and, at the same time, when the yarn is put into the fly shuttle to weave, it must run off the cop freely, and yet not in more than a single turn at once. The self-actor accomplishes this in addition to all the rest of the complicated movements, and all these multifarious duties must be performed absolutely to time, and therefore very positively. Compared with the self-actor, the spinning frame of Richard Arkwright was as a barrow to a motor car. It is curious that, though Roberts has been dead forty years, no sort of recognition of his merits had, we believe, been made previous to the unveiling of a bust at Aberystwyth a year or two ago. And the self-acting mule was but one of many inventions made by him in every department of engineering and mechanical industry. He was a genius as an inventor, and a brilliant exception to the rule that inventors are always impossible sort of men, for he was successful in life in the vulgar sense or pecuniarily, and died wealthy.

EVER since the introduction of rapid-cutting steels by Messrs. Taylor and White the whole subject of the relations of actual metal-cutting to the conduct of machining operations in the workshop has been a vital question for solu-

tion. With the announcement of the production of an improved high-speed steel by Messrs. Jonas and Colver, of Sheffield, claimed to possess at least quadruple cutting efficiency over the existing rapid-cutting steels, this question may assume an intensified importance.

A finished product of the machine shop represents the resultant of a sequence of operations, of which the actual removal of the superfluous metal forms only a part. Formerly, with inferior machinery and ordinary carbon steels, permitting only moderate cuts and speeds, the proportional influence of the turning, planing, boring and similar operations upon the cost of the finished product was much greater than it now is. The designing engineer often modified his plans in such a manner as to minimize the amount of metal to be removed, rightly considering such efforts of importance in connection with the economics of manufacturing. As machining processes were improved, it became evident that the removal of the excess metal might well be less costly than the methods formerly in vogue. An excellent example is found in a comparison between the old-time method of forging collars and similar enlargements upon turned work in order to reduce the actual amount of metal to be removed in the lathe; as opposed to the modern system of using the turret-lathe or similar machine for the production of the piece from solid stock of the maximum dimensions. The cost of the metal and of its removal became much less than the cost of the forging.

With the advent of high-speed steels and the consequent speeding up of machine tools, the importance of the cutting operation began to assume a new relation to the other elements of the problem. Placing the piece in the machine took as long as ever, unless improved appliances and methods of handling kept pace with the actual work of cutting. The relative importance of the overhead burden, of the efficiency of the machine tool, of the efficiency of the man himself and of the men by whom he was directed and utilized—these all began to show a preponderating influence upon costs, and to-day the management of an engineering establishment, if it is to compete successfully with its rivals, must consider seriously many things which formerly were held of secondary importance.

Just how far the development of cutting tools and processes may yet further disturb the equilibrium of the machine shop and its methods remains to be seen. This much we may assume, at least, in the light of past experience, that an increase of efficiency in what has already lost a large part of its claim to be the primary factor in manufacturing costs must have a continually decreasing influence upon a final result of which it is only a single element.

IT seems to be a *sine qua non* that to secure really high efficiency a steam turbine must exhaust into a very good vacuum. No better vacuum can be secured under any circumstances than that proper to the temperature of the condenser. If the temperature is 125 degrees F., no vacuum is possible above 26 inches. With 25 degrees less temperature an additional two inches is possible. But the trouble in practice is that the temperature is almost always lower than that proper to the vacuum. Why should this be? It is almost certainly because of the presence of air.

Where surface condensation is in use there ought to be practically no air in the condenser, and it ought to be possible to employ a mere rudimentary air pump. But this desirable condition is not attained in practice. The feed-water may be free from air, due to the fact that it has been boiled and reboiled and put under an exhauster and very thoroughly purged of air. But air enters at badly packed glands, and at bad pipe-

joints, and at the feed pump, and this air when it gets into the condenser occupies a volume many times what it would occupy at atmospheric pressure. In order to deal with all the air which leaks into the vacuum system generally, the volume generated by the air-pump bucket in a given time must be equal to the volume of the air leaking in that time multiplied by $\frac{V}{v}$ in which V is the volume of air at condenser pressure and v is the volume at atmospheric pressure. This fraction $\frac{V}{v}$ has the ratio $\frac{14.7 - K}{14.7}$, K being the absolute pressure in the condenser.

For 100 degrees F. of temperature K should be 0.944, or 28 inches. With a really good vacuum this ratio $\frac{V}{v}$ becomes very large indeed, and it increases very rapidly indeed at vacua above 26 inches. It is, therefore, easy to understand that, with a very little excess of air leakage, the capacity of an air pump to overcome it may be overtoned. In such a case the intensity of the vacuum will fall off until the air increases in density sufficiently to enable the air pump to take hold of a sufficient weight of air, each stroke to balance the weight which enters. To raise a vacuum from 26 to 28 inches requires the air pump to be doubled in size. To avoid so great an enlargement of the pump the intensifier has been brought into use. The condenser is arranged on a slope, so that the condensed steam flows away to one end and falls to the air pump. Air is drawn from the condenser through an opening and propelled by a steam jet through a small secondary condenser into the air pump. The capacity of the jet is such that it will probably halve the volume of the air. Thus the extremely rarified air of a 28-inch vacuum is pushed up in pressure and taken hold of by an air pump large enough to maintain the vacuum at 28 inches if fed with air corresponding only to a 26-inches vacuum. This the steam jet enables it to do. Information is lacking as to the proportions adopted for the air pumps in these combinations. Why is this intensifying action necessary? Are we not always informed that there are no leaking glands about a turbine, and that air leakage is practically prevented altogether? If the leakage is so very small there can be no need for a large air pump, yet the steam jet, combined with an air pump of usual dimensions, is a large pump in effect, for it is only another form of the compound principle applied to a form of air compressor which compresses to the atmosphere as a maximum. Whatever the proportions, however, the use of the intensifier is interesting and the principle is sound, and may be employed with advantage to diminish the size of the ordinary air pump. It is, of course, to be noted that no attempt need be made to improve a vacuum beyond that proper to the temperature of the condenser; but there is no reason why a vacuum of that corresponding intensity should not be reached. It always would be reached in the total absence of air, and, where not reached, the cause must always be sought in air leakage. A good vacuum is valuable to a steam engine, especially to a turbine; but it is bad practice to make efforts to maintain specially good vacuum until it has been proved that, with everything at rest, the intensity of it will remain but little unchanged in an hour's observation. Apparatus can be made as airtight as this test demands, and when it is so tight it should be possible very seriously to reduce the volume generated by the air-pump bucket, remembering that but for air the condenser pump would be practically of the same size as the feed-pump. It is only because of air that it is needed any larger.

WITH the launch of the *Delaware,* the progress of the extension of the United States Navy goes on, and the fleet of big battleships, which will include the *North Dakota,* the *Florida* and the *Utah,* has made one more move towards realization.

The *Delaware,* which took the water at Newport News successfully on February 6, is a sister ship to the *North Dakota,* being 510 feet in length, with a trial displacement of 20,000 tons and a speed of 21 knots. With a bunker capacity of 2,500 tons, she will be able to maintain a speed of 10 knots for twenty-eight days, this corresponding to a cruising radius of about 6,700 miles.

The armament of the *Delaware* will consist of a main battery of ten 12-inch guns, in addition to fourteen 5-inch guns and a number of smaller pieces.

With this displacement, exceeding that of the *Dreadnought* by more than 2,000 tons, and being more than 700 tons greater than that of the *Vanguard*—the latest vessel of the British *Dreadnought* class—the *Delaware* is a notable addition to the navy of the United States. As it now stands, the vessels of the *Dakota* class exceed in displacement and broadside fire any battleships except the Brazilian ships *Minaes Geraes* and *San Paulo,* and these latter are surpassed slightly in displacement by the American battleships. It is true that the *North Dakota* class will be exceeded by the new 26,000-ton ships to be authorized, but these will not be available for at least three years.

It is interesting to note that the American Navy has not yet abandoned the reciprocating engine as the motive power of the latest battleships, the *Delaware* being designed with vertical, triple-expansion, reciprocating engines. The steam turbine does not yet appear to have made its way in the battleship class, notwithstanding the success of the propelling machinery of the scouts *Salem* and *Chester.*

In the British Navy the experience with the steam turbine appears to have been satisfactory, since all the vessels of the *Dreadnought* class are planned for turbine propulsion. The *Neptune,* of which the keel has been laid and on which work is making rapid progress, is to have a displacement of slightly over 20,000 tons and a main armament of ten 12-inch guns, practically corresponding to that of the *Delaware.*

This whole subject of the extension of naval equipment is one which has already aroused active discussion, and while it has doubtless been planned for the best interests of the respective nations, according to the views of government experts, it seems to partake rather of a succession of hurried imitations than of the exercise of scientific initiative. When the duel of the *Merrimac* and the *Monitor* took place in Hampton Roads in 1862, the navies of the world consisted wholly of wooden vessels, and the sudden appearance of the ironclad rendered the equipment of practically every naval power obsolete. To-day the times are ripe for the development of some entirely new weapon of attack and defense, and its appearance may work a similar revolution and render some of the battleships of to-day ancient history before they leave the ways. Just what new methods may be employed cannot now be predicted; they may involve navigation in the air above or in the water beneath, but whatever they may be, they will make the country which has had the initiative to produce them the master of the nations which have preferred the easier policy of imitation.

AUGUSTE RATEAU

A BIOGRAPHICAL SKETCH

ALTHOUGH the practical development of machines of the steam turbine type dates from the pioneer work of De Laval in Sweden and of Parsons in England, it is a matter of record that France perceived the importance and possibilities of this form of motor still earlier. In the pages of the *Comptes Rendus* of the French Academy so long ago as 1853, the French engineer Tournaire described, in a most complete manner, the multiple-stage steam turbine as it was afterwards practically developed by Parsons. In like manner France has produced one of the most energetic and successful engineers in turbine practice, Professor Auguste Rateau, whose portrait is presented to our readers this month.

The work of Professor Rateau was originally devoted to mining engineering, both in connection with government undertakings and as professor at the Ecole des Mines at St. Etienne. As long ago as 1890 Professor Rateau devoted much attention to the steam turbine, beginning with single-wheel machines, using a rotor of the Pelton water-wheel type, this being followed by his well-known multicellular turbine in 1900.

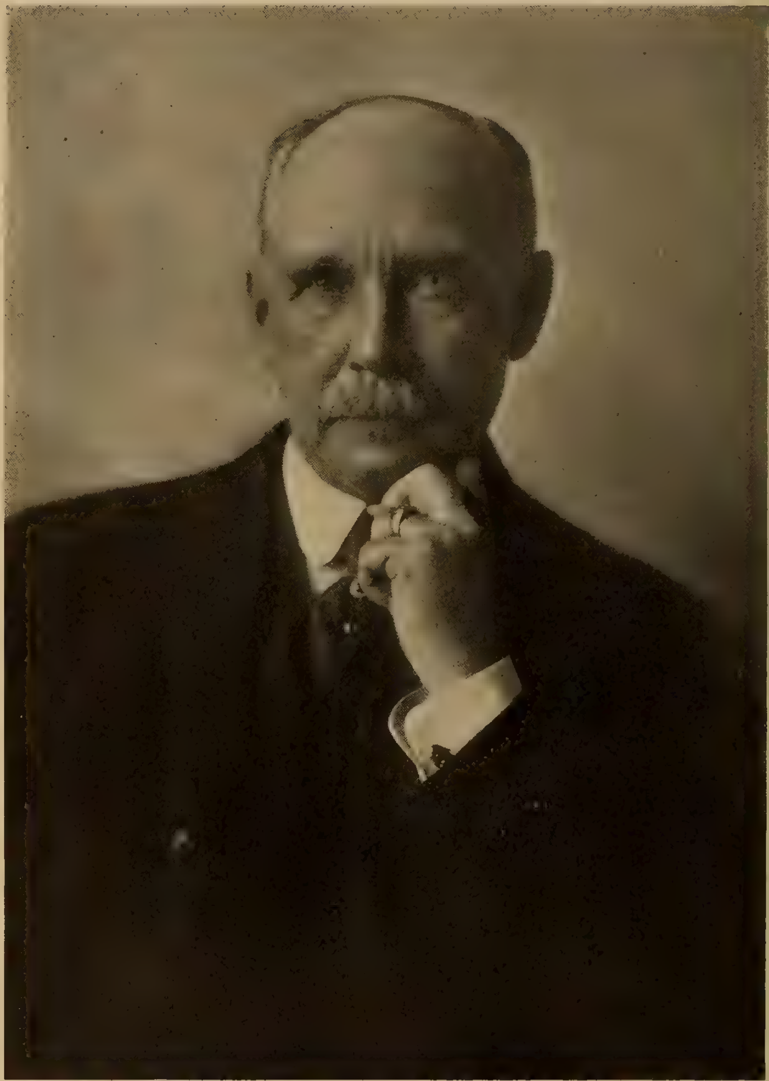
Prior to this Professor Rateau had become well known as an author in connection with turbine machinery of all kinds, his articles on "Turbo-Machines" in the pages of the *Revue de Mécanique* being devoted largely to hydraulic turbines, these papers being published in 1897, while an important paper upon the same subject was contributed by him to the proceedings of the International Engineering Congress held in connection with the Paris Exposition of 1900. At the same Congress Professor Rateau presented an exhaustive discussion upon the steam turbine, this paper treating of the single-wheel machine, the multicellular steam turbine and the general methods of computing the efficiency of such machines.

In the course of these practical and theoretical studies Professor Rateau was led to consider the possibilities of the low-pressure steam turbine, especially as an auxiliary in connection with reciprocating engines of intermittent operation, unable to utilize the expansive force of the steam to the best advantage. Such cases are especially to be found in pumping engines, steam pumps, winding engines of mines, and engines operated in rolling-mill work. For such situations Professor Rateau devised the so-called "steam accumulator," this consisting of a reservoir into which the intermittent discharges of exhaust steam from the pump, winding engine or other engine were delivered, the reservoir containing either masses of iron or a considerable volume of water to absorb the heat of the steam and to give it out in such a manner that the irregular puffs or varying pressures were converted into a flow practically continuous in nature, and having a pressure nearly uniform, corresponding to the average of the irregular pressures delivered into the accumulator. Such a continuous flow is eminently adapted to be delivered into a low-pressure steam turbine, and in this manner a large amount of power, capable of operating an electric generator, could be derived from the exhaust discharges of steam formerly wasted. Such combinations of reciprocating engines and Rateau

low-pressure steam turbines have been installed in a number of important works with excellent results.

Professor Rateau has given much attention to the development of the multiple centrifugal pump and the multiple pressure blower, and the machines of this type which have been constructed by Messrs. Sautter, Harlé & Cie., Brown, Boveri & Co., and other firms from his designs have shown a very high efficiency. The problem of the rotary-pressure blower is especially important in connection with the successful development of the gas turbine, since it would be of little value to produce a rotary gas engine and require a reciprocating air compressor to supply it. Professor Rateau has, therefore, designed a special type of high-pressure, multiple rotary compressor for use with the gas turbine devised by the late René Armengaud and his associate, M. Lemale, this compressor delivering air at pressures of 6 to 7 atmospheres, with an efficiency as high as 67 per cent. A compressor of this type is shown in connection with the article by M. Armengaud in the issue of this magazine for January, 1907, and also as erected in the experimental shops of the Société de Turbomoteurs at St. Denis in the article upon the gas turbine by M. Alfred Barbezat in the issue of CASSIER'S MAGAZINE for April, 1908.

Professor Rateau is a member of the Council of the Société d'Encouragement pour l'Industrie Nationale, and is a member of the Société Internationale des Electriciens, and also a member of the Société des Ingénieurs Civils de France. He is well known in the United States, having many business and personal friends in America, and having visited this country in 1904.



D. W. BRUNTON

PRESIDENT AMERICAN INSTITUTE OF MINING ENGINEERS

See page 740.

CASSIER'S MAGAZINE

VOL. XXXV APRIL, 1909 No. 6

THE DEVELOPMENT OF AERIAL NAVIGATION

By Henry Harrison Suplee

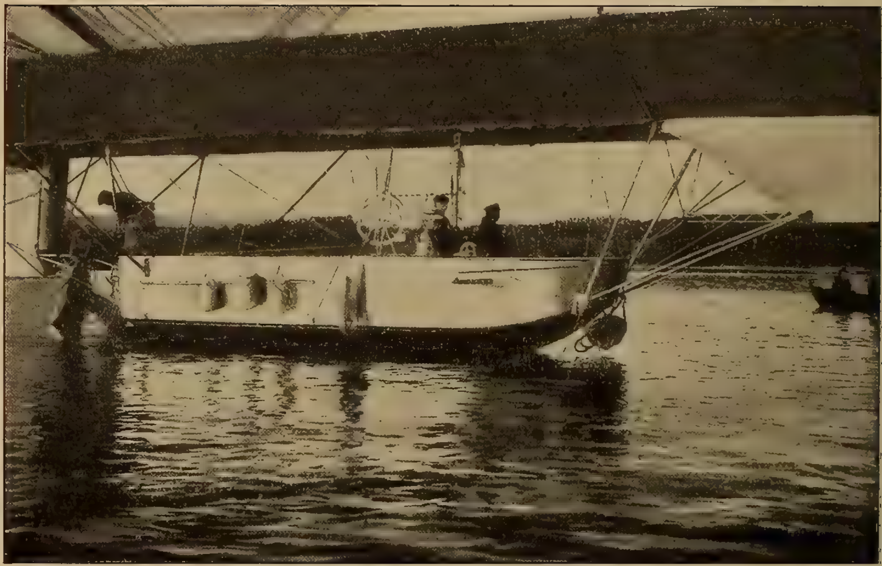
RENARD AND KREBS' AIRSHIP LA FRANCE, 1884

DURING the past few years there has been developed an increasing interest in the solution of a problem which, for more than a hundred years, has had a semi-scientific status, and which has now attained a position which fully entitles it to be considered a department of the applied science of engineering—the problem of the controlled navigation of the air.

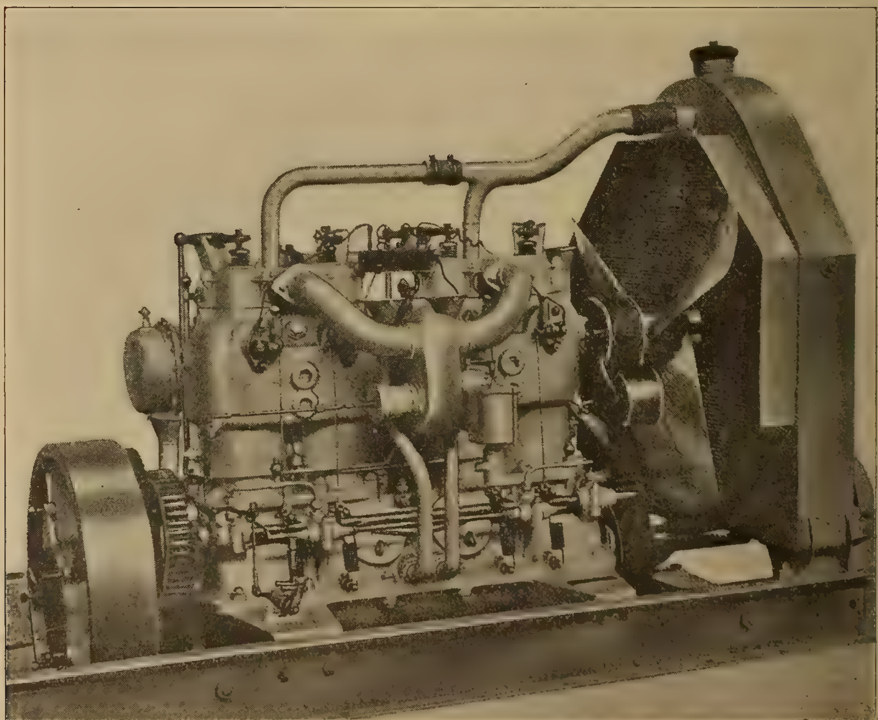
Naturally an inhabitant of the solid land, man has perceived about him animals living on land, in the water and in the air, and from time immemorial he has added to his natural habitat a certain occupancy of the water, from the first crude raft to the modern *Mauretania;* but during nearly the entire period of his existence he has been compelled to witness the free possession of the atmosphere by the birds, a possession wholly unattainable by him. Even with his present command of the resources and forces of Nature, with his ability to manufacture and control power, his attempts to sustain himself in the air, and to use it as a highway for his movements, have been singularly tardy and ineffective.

The subject has certainly had its attractions and fascinations from an early period, and in the attributes of superior powers from the dawn of legend the ability to traverse the air has almost invariably been included as one of the highest. Every mythology has its example of beings who could fly, and of traditions of mortals who have attempted the feat, mostly with disastrous results as to these latter; and until about the last decade one of the frequent associations with aeronautics was that of a visionary temperament, to put it in the mildest form. To-day, however, the balloon, the dirigible, the aeroplane—these have become familiar terms to the man in the street, and, like some other things which have later settled into daily usefulness, aeronautics has entered the field of sport, from which it bids fair to be developed into the service of everyday life.

Leaving aside the early tales and legends, there is little doubt that the beginnings of modern aeronautics followed in due course the revival of



GERMAN DIRIGIBLE ZEPPELIN, SHOWING DETAILS OF CAR



100-H. P. MOTOR FOR THE ZEPPELIN AIRSHIP, BUILT BY THE DAIMLER MOTOREN-GESELLSCHAFT

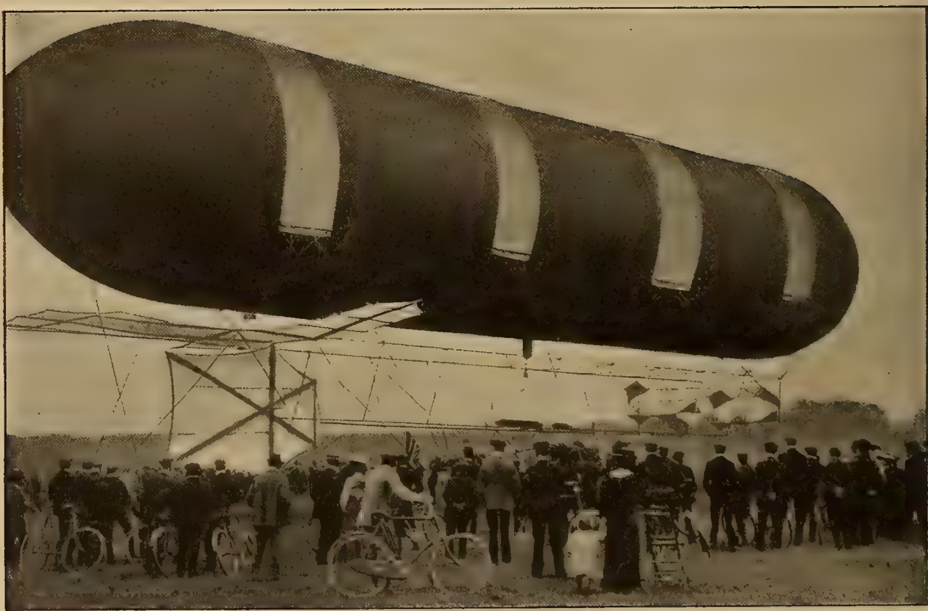
GERMAN DIRIGIBLE ZEPPELIN WITH FLOATING HANGAR

learning in the sixteenth century. Some of the earliest attempts at flying resembled very closely the most recent methods of investigating the aeroplane. The experimenter, fitted with some supporting device, generally imitated from the wings of a bird, jumped from an elevation and attempted to glide to the ground. Such attempts usually resulted disastrously, as might have been expected from the clumsy nature of the devices, as they are described in current records. In some instances, however, a small measure of success was attained, at least in that the experimenters reached the ground in safety after gliding a limited distance; but the failures greatly outnumbered any such partial successes.

With the increase in the knowledge of the physics of the atmosphere,

LA VILLE DE PARIS. TESTING THE ENGINE BEFORE FLIGHT

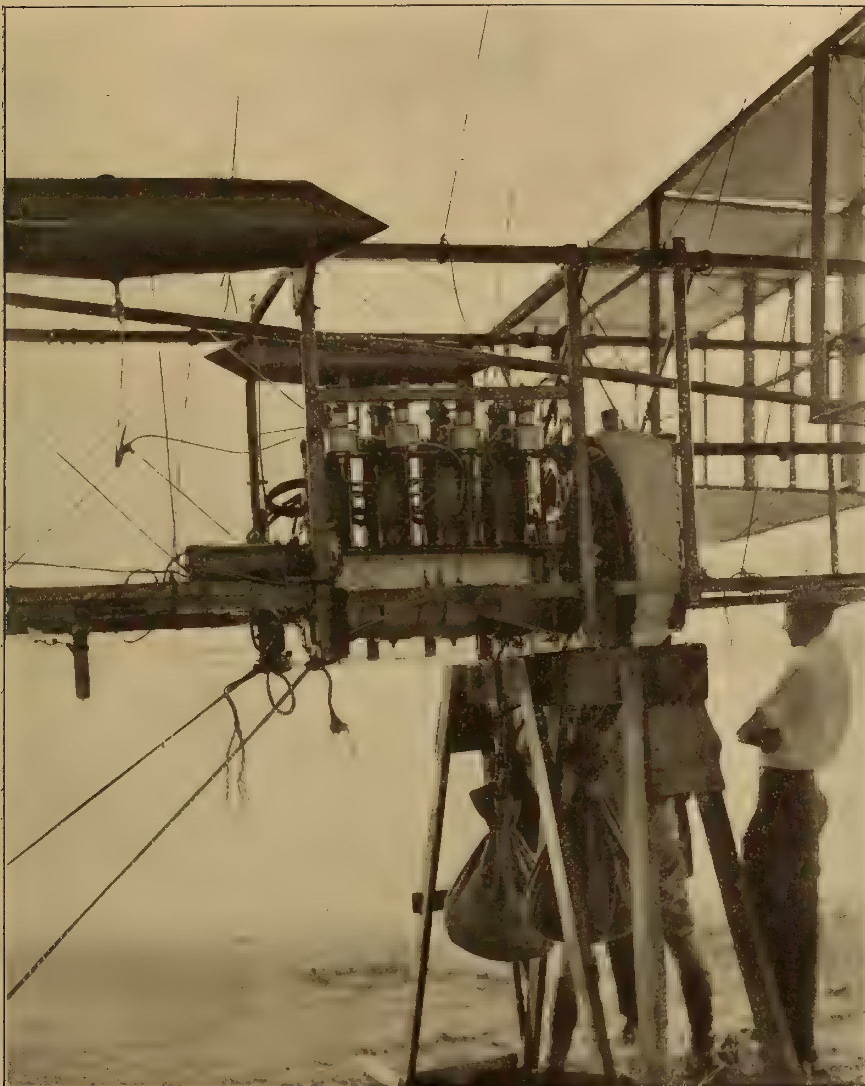
DETAILS OF CAR OF THE PATRIE



ENGLISH DIRIGIBLE "NULLI SECUNDUS"

THE FRENCH DIRIGIBLE "PATRIE"

U. S. SIGNAL CORPS DIRIGIBLE NO. 1 IN FLIGHT, FORT MYER, VA., AUGUST, 1908



DETAILS OF CAR OF THE U. S. SIGNAL CORPS DIRIGIBLE NO. 1

however, other ideas began to appear. Of these the most notable was that of the Jesuit, Francisco Lana, of Brescia. Lana, who appears to have understood the investigations of Torricelli upon the barometer, proposed to make use of the newly-discovered weight of the atmosphere to support bodies which should displace a volume of air greater in weight than themselves. His ideas show a most curious intermingling of correct theory and impracticable construction, since he proposed to make use of large copper spheres so thin as to weigh less than the volume of air which they displaced. He assumed that by exhausting the air from these vessels they would float in the atmosphere, and his design shows a car supported by four such copper vacuum balloons, as they might be

termed. That any such balloons would necessarily be so weak as to be crushed by the atmospheric pressure on the outside does not seem to have occurred to Lana; but his plan is, in a certain sense, a curious forerunner of the use of the aluminum reinforcement of Zeppelin in these latter days. Lana published his plan in 1670, but it was not for more than a hundred years that the real supporting power of the atmosphere was applied by Montgolfier.

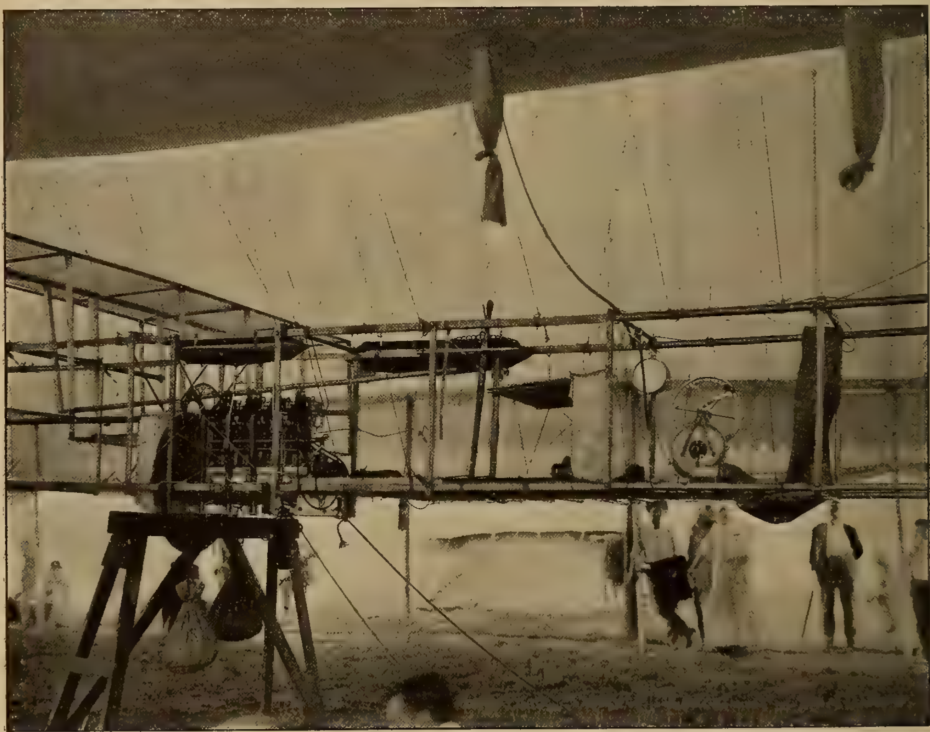
U. S. SIGNAL CORPS DIRIGIBLE NO. 1, SHOWING DETAILS OF FRONT MANEUVERING PLANES

It is a curious fact that the first fire balloon was made by Montgolfier under an entire misconception of the real facts. Priestley had published his experiments upon different kinds of air, as gases were then called, and Stephen Montgolfier, assuming that smoke was a particularly light kind of air which ascended because of its levity, undertook, with the aid of his brother Joseph, to enclose some smoke in a light bag and see if it would not ascend. The first experiment, made in June, 1783, with a balloon about 30 feet in diameter, inflated over a fire of burning straw, was eminently successful, and numerous repetitions of the experiment followed. Physicists soon realized that it was the rarefaction of the air by heat which gave the difference in specific gravity and caused the ascent, and Charles, at Paris, a few months after the first experiment with the fire balloon of Montgolfier, made a balloon filled with hydrogen gas, generated from sulphuric acid and iron filings. After sending up balloons carrying animals, ascents were made by various individuals, and the period of experimental aeronautics may be said to have fairly begun.

When the manufacture of coal gas for purposes of illumination became general this material superseded hydrogen, because of the reduction in cost, notwithstanding its inferior buoyancy as compared with pure hydrogen, and thus it became possible to float in the air to great heights, and to drift long distances in the currents of the upper air.

ANOTHER VIEW OF AMERICAN DIRIGIBLE NO. 1 IN FLIGHT

Very soon after the practical demonstration that ascents could be made in a car suspended beneath a bag inflated with gas the limitations of the method were realized, and for a long time the balloon fell into the position of a sort of gigantic scientific toy, the accompaniment of country fairs and of holiday celebrations; but almost wholly failed to fulfill the great expectations which had been raised by its first appearances. Certain ascents, notably those by Glaisher, in Europe, and by Wise, in America, were conducted for the study of meteorological conditions in the upper air; but, apart from these, little was done in the way of scientific development. Some attempts were made to utilize the balloon in military operations, one of the first of these being at the battle of Fleurus in 1794, others in the French campaign in Algeria in 1830 and in the Italian war of 1859; but there is no record of really valuable results following. Probably the most useful service ever rendered by the balloon in time of war was in the siege of Paris in 1870-1871, during which sixty-four balloons left the besieged city, carrying out passengers, Gambetta among them, as well as carrier pigeons, to be used for bringing communications into the city from without.



DETAILS OF CAR OF DIRIGIBLE NO. 1

As in nearly every other department of applied science, aeronautics is dependent upon progress in other departments of work for its advancement. A drifting gas bag in itself can never be considered a manageable piece of apparatus, and until some method of propelling and guiding could be devised it had to remain an interesting piece of incompleteness. During its earlier period any prime mover available for propulsion was found far too heavy for practical service, and for a time the pos-

sibility of such a combination was abandoned.

In the meantime other departments of mechanical engineering were progressing towards a point where the results should become available for aerial service. In naval construction the demand for light, swift, high-powered torpedo boats and destroyers led to the design of engines of high rotative speed and supplied with steam from water-tube boilers operating at high pressures, the result being a notable reduction in weight for the amount of power developed. It is estimated that the machinery of a warship of the design of the middle of the nineteenth century represented a weight of more than 400 pounds per horse-power, while the efforts to increase power and to reduce weight in torpedo boats brought the proportion down to about 60 pounds per horse-power. This, however, was still far too great for service in the air, and the balloon had to remain a drifting curiosity for some time longer.

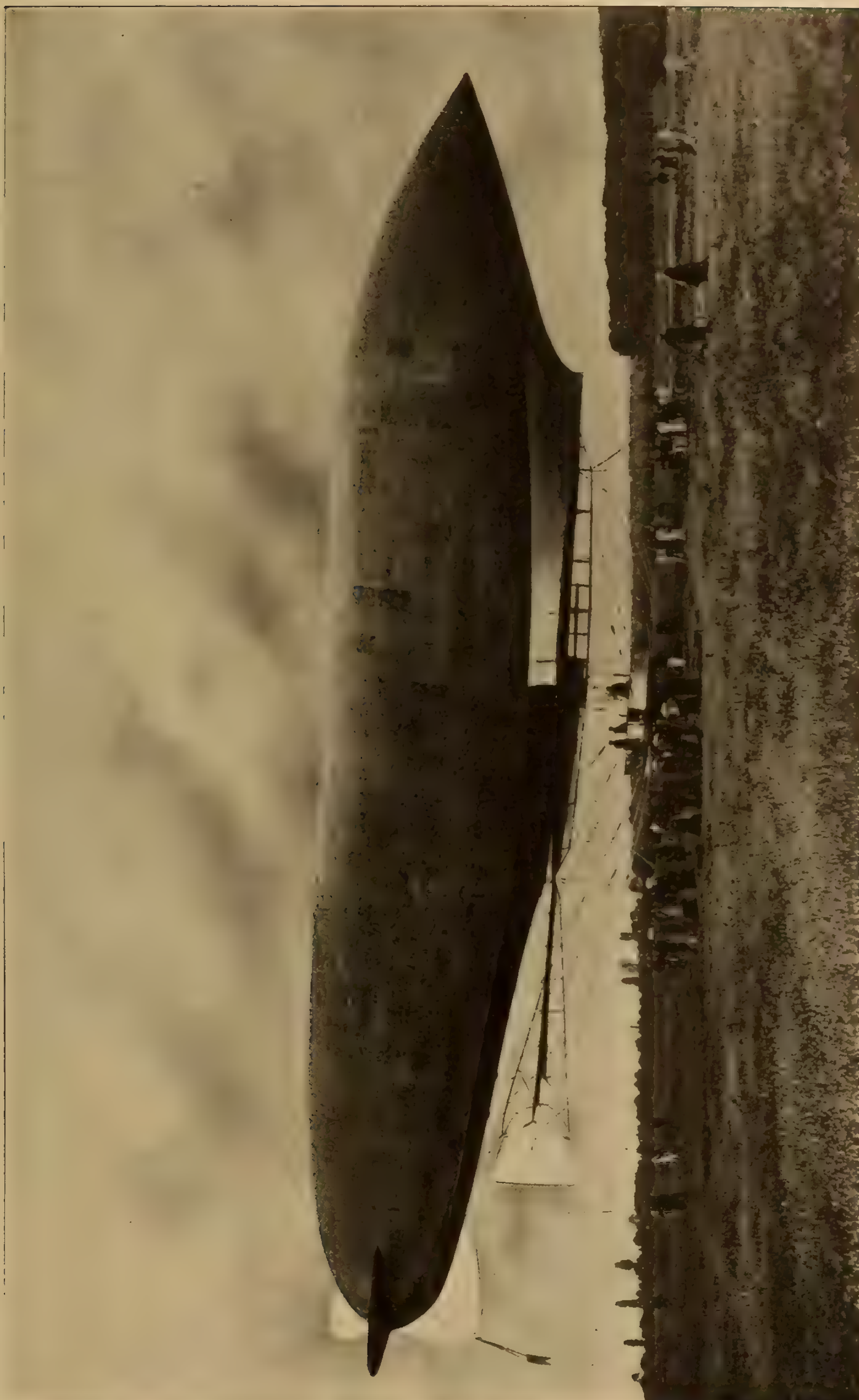
Meanwhile efforts had been industriously progressing on altogether different lines, and a variety of attempts had been made to produce flying machines dependent upon some other means than the buoyancy of a gas bag for their support. It was plainly evident that birds are heavier than the air in which they fly, and that while they are raised by muscular effort, they are often seen to glide for long distances without apparent effort. Every boy knows how to make a kite, which itself is always heavier than air, and yet which is capable of ascending to great heights and supporting considerable weights. These facts and similar observations have formed the basis of a long line of experimental machines, called by Nadar the *plus lourd que l'air*, to differentiate them from the balloon type.

Naturally, many attempts were

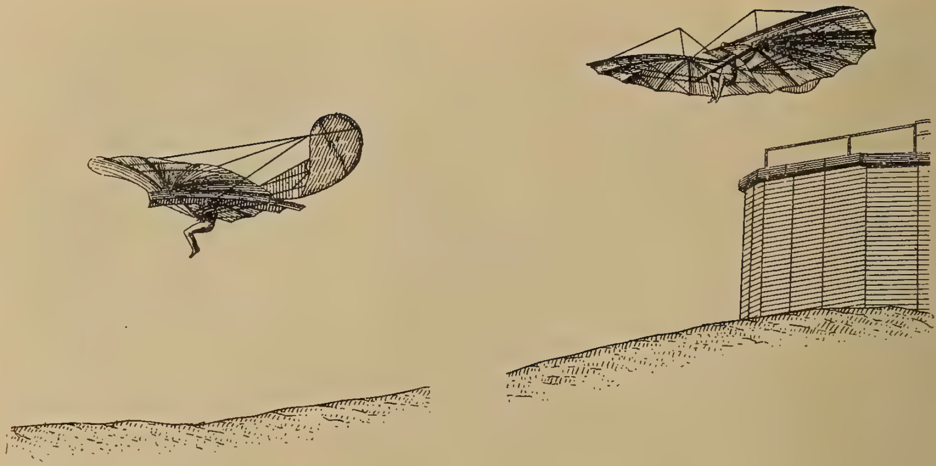
STEEL BALLOON HOUSE, GASOMETER AND HYDROGEN GENERATING-PLANT SIGNAL CORPS POST, FORT OMAHA, NEB.

made to imitate the action of a bird, and many careful studies of bird flight have been undertaken in the effort to extort the secret from Nature. Scientific studies of the movements of birds in flight have been conducted by Drzwiecki, by Marey, Pettigrew and others, and especially since the development of instantaneous photography and of apparatus for taking and combining series of photographs with sufficient rapidity to permit of the subsequent reproduction and study of the movements this question has been given critical investigation. It does not follow, however, that the method used by the bird, even if it could be reproduced, would be the most effective for man. He has not copied the action of the fish for navigation in the water either upon or beneath the surface, and it is becoming apparent that the successful flying machine will not be a precise copy of the eagle or the condor. Nevertheless, some very interesting artificial birds have been constructed, and the flying models of Penaud and of Trouvé are curious examples of mechanical ingenuity. More promising machines are those of the so-called helicoptère type, using revolving propellers to lift and to propel themselves in the air. Screws arranged for the purpose of lifting themselves in the air have not been proved very efficient devices, experimental determinations showing that an expenditure of 1 horse-power, with a well-proportioned screw, is capable of sustaining about 25 pounds in the air. The motor and all its appurtenances, therefore, must be lighter than 25 pounds per horse-power developed in order to lift itself. For a long time it was not found practicable to produce such a light motor; but modern gasoline engines are built of weights far within these limits of weight, so that machines of the helicoptère type are not impossible. The danger of a machine wholly dependent upon the maintenance of the

VILLE DE BORDEAUX AS SHOWN AT THE PARIS EXPOSITION DECEMBER, 1908. CAPACITY, 3,000 CUBIC METRES. RENAULT MOTOR, 80-90 HORSE-POWER



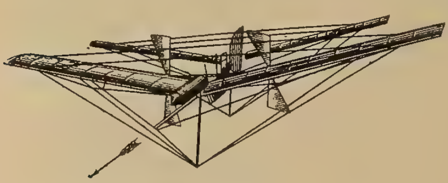
FRENCH DIRIGIBLE "REPUBLIQUE"



LILIENTHAL AND HIS GLIDER

speed of its engines for its support, however, has discouraged effort in this direction, and engineers have turned rather to the example of the kite—that is to say, to the aeroplane—in their efforts to make a successful flying machine independent of a gas balloon for its support.

The kite, as every boy knows, will not rise unless there is sufficient wind. The sustaining surface is attached to the string at such a point that the kite is held at the proper angle to the wind, while equilibrium is secured by the tail and its bobs. Very early in the history of aeronautics it was seen that, if a revolving propeller could be substituted for the pull of the string, the action of the kite could be reproduced with a free apparatus, while if the propeller had sufficient power to move the whole affair along at a sufficient speed, its own velocity would take the place of the wind upon which the kite is so dependent. All this, however, involved a motor of much less weight for its power than anything available at the time, and such schemes necessarily existed only on paper. Two experimenters only appeared to have sufficient faith in the soundness of the principle to attempt actual construction—Mr. Hiram Maxim, now Sir Hiram, in England, and Professor S. P. Langley, formerly secretary of the Smithsonian Institution, at Washington. Both of these investigators devoted much of their effort to the design and construction of very light steam engines, and with much success, Mr. Maxim making an engine weighing only about 8 pounds per horse-power, including boiler, water and auxiliary apparatus.



PROFESSOR LANGLEY'S AEROPLANE

The engine and machinery built by Langley was still lighter, every detail being cut down to the minimum weight possible; and it is possible that, had other elements in the Langley machine sustained their part, the engine would have been found sufficiently light and effective for all the purposes for which it was intended.

Taking up the modern development of machines of both types, and passing over those which existed wholly on paper, we find that the application of scientific principles to the dirigible balloon in a practical

manner was largely due to Henri Giffard, the French engineer, well known for his invention of the injector for feeding steam boilers. Giffard actually constructed a machine in 1852 having a spindle-shaped balloon 44 metres in length and 12 metres in diameter and a volume of 2,000 cubic metres. This was equipped with a steam engine of 3 horse-power, operating a screw propeller, and the machine was successfully navigated at a speed of 2 to 3 metres per second.

Although the impracticability of obtaining sufficient power within reasonable limits of weight prevented this machine from becoming a success, the experiments were considered of sufficient importance to cause a representation of the dirigible to be placed upon the memorial to Giffard in the house of the Société des Ingénieurs Civils de France.

The next practical experiment was made by Haenlein, at Brünn, Austria, in 1872, and is of especial interest, as it involved the use of a gas engine as motive power, the balloon being cylindrical in form, with pointed ends, having a total length of 50 metres and a volume of 2,400 cubic metres. With a development of 2.8 horse-power a speed of 1.3 metres per second was attained and the balloon navigated under control.

It is now generally conceded that the experiments which led to the present status of the dirigible balloon were those undertaken by Col. Renard for the French army service in 1884. Renard, who lived to see the success of the principles he so intelligently advocated, built a dirigible, which was called *La France,* with which a number of successful experiments were conducted, and which undoubtedly formed a guide for practically all plans down to very recent date, with but few exceptions.

The Renard balloon was formed in

WRIGHT BROTHERS' AEROPLANE. FORT MYER, VA., SEPT. 9, 1908

accordance with what has since been demonstrated to be correct principles, being of so-called fusiform shape, the maximum section being one-fourth of the length from the front end. The total length of the gas bag was 50.42 metres, and the maximum diameter 8.4 metres, the volume being 1,864 cubic metres. The balloon was furnished with a *ballonet,* or interior balloon, capable of being pumped full of air, thus keeping the main gas bag taut at all times; and the motive power, a Gramme electric motor, capable of developing about 9 horse-power, was supplied with current from chromium chloride batteries specially designed for the service.

From contemporary accounts of these experiments some interesting information may be obtained, and it will be seen that in one element only, that of reduction in the weight of motive power, have most of the modern dirigibles improved upon the design of Renard.

The distribution of weights in *La France* was as follows:

	Pounds
Balloon and ballonet	811
Netting and suspension	279
Complete car	994
Rudder	101
Propeller	91
Motor	216
Mechanical connections	104
Driving shaft	67
Battery and adjuncts	968
Two passengers	308
Ballast	471
	4,410

Of this weight it will be seen that the two items of the electric motor and its battery amount to 1,184 pounds, which, at 9 horse-power, gives about 132 pounds per horse-power. With a modern automobile engine, weighing, say, 10 pounds per horse-power, there would be developed more than 100 horse-power for the same weight.

With this balloon, on August 9, 1884, Col. Renard, accompanied by Capt. Krebs, made a trip from Meudon to the Hermitage of Villebon, a distance of about 7 kilometres, effect-

DETAILS OF CONSTRUCTION OF WRIGHT BROTHERS' AEROPLANE

ORVILLE WRIGHT IN FULL FLIGHT. SEPT. 9, 1908

READY FOR THE START, ORVILLE WRIGHT AND PASSENGER. SEPT. 12, 1908

ing a turn of about 300 metres radius, and returning to the point of departure, the machine being at all times under complete control. Other trips were made during 1884, with similar results; but the impracticability of securing a light-weight motor rendered further developments impracticable, and, as the experiments were made for the use of the War Department of the French Government, many details of the results were kept only upon the official records.

Although various experimenters were at work during the latter years of the nineteenth century, no material results were obtained except in the cases of Zeppelin, in Germany, and of the Brazilian, Santos-Dumont, in France. Both of these investigators began work in 1898, the latter practically along the same lines as Renard, with the substitution of the light gasoline motor for the heavy electric motor and battery, while the former undertook to add to the idea of the inflated gas bag the use of a rigid framework of aluminum. The experiments of Zeppelin continued from 1898 down to the present time, four machines having been constructed and operated. The latest of the Zeppelin dirigibles had a rigid framework of aluminum alloy 446 feet long and 42 feet 6 inches in diameter, covered with a fabric made of cotton and rubber. Within this framework were sixteen separate gas bags, these being in chambers separated from each other by partitions of sheet aluminum. These gas bags had a total volume of 460,000 cubic feet, giving a lifting power of about 32,000 pounds. The rigid frame permits the attachment of the two cars in a firm manner, and each car was fitted with a

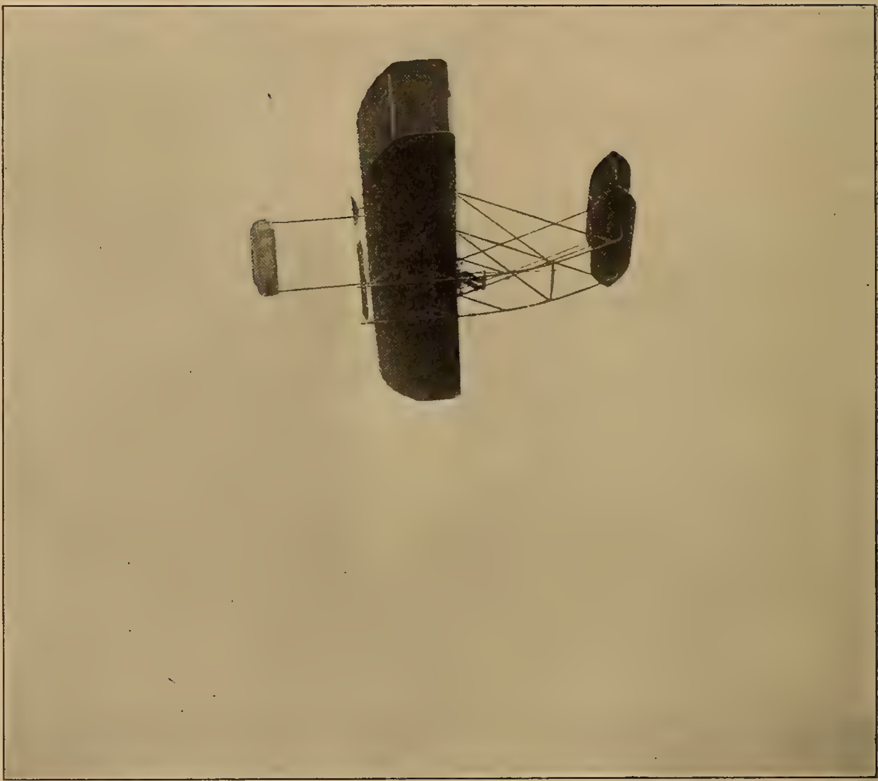
WRIGHT BROTHERS' AEROPLANE, FORT MYER, VA. TIME OF FLIGHT, ONE HOUR AND FOURTEEN MINUTES AND TWENTY SECONDS. SEPT. 12, 1908

motor and separate pair of propellers.

The Zeppelin balloon was fitted with sets of horizontal planes on each side, these being so arranged as to be inclined, and thus act, to a certain extent, as aeroplanes, and to assist in the control of the ascent and descent of the machine. Zeppelin's experiments have been made at Friedrichshafen, on Lake Constance, the balloon rising from a float on the lake.

During 1898 this machine made two notable flights, one in July having a duration of twelve hours and extending as far as Zürich and return, a total distance of 235 miles, while the other lasted nearly twenty-three hours and covered 38 miles, the balloon descending near Stuttgart, and there meeting with an accident, being destroyed by a storm. Popular subscriptions have resulted in the raising of a large sum of

ORVILLE WRIGHT AND PASSENGER. TIME OF FLIGHT, NINE MINUTES AND SIX SECONDS. SEPT. 12, 1908



WRIGHT BROTHERS' AEROPLANE. FORT MYER VA., SEPT. 12, 1908

money for the continuance of the experiments, and there is little doubt that Zeppelin will succeed in meeting the requirements of the German Government by making a trip of twenty-four hours' duration under perfect control.

The experiments of Santos-Dumont in France have been on a much smaller scale, as regards size of machines, but include some fourteen dirigible balloons, these being practically sporting machines, having spindle-shaped gas bags and gasoline motors. M. Santos-Dumont succeeded, on October 19, 1902, in winning the Deutsch prize of 100,000 francs by making a trip from the "Aerostation Park" of the French aeroclub, circling the Eiffel Tower and returning in 30 minutes 41 seconds. His machine had a balloon 33 metres long and 6 metres diameter, with a volume of 622 cubic metres, and was propelled by a Buchet motor of 16 horse-power at a speed of about 7 metres per second.

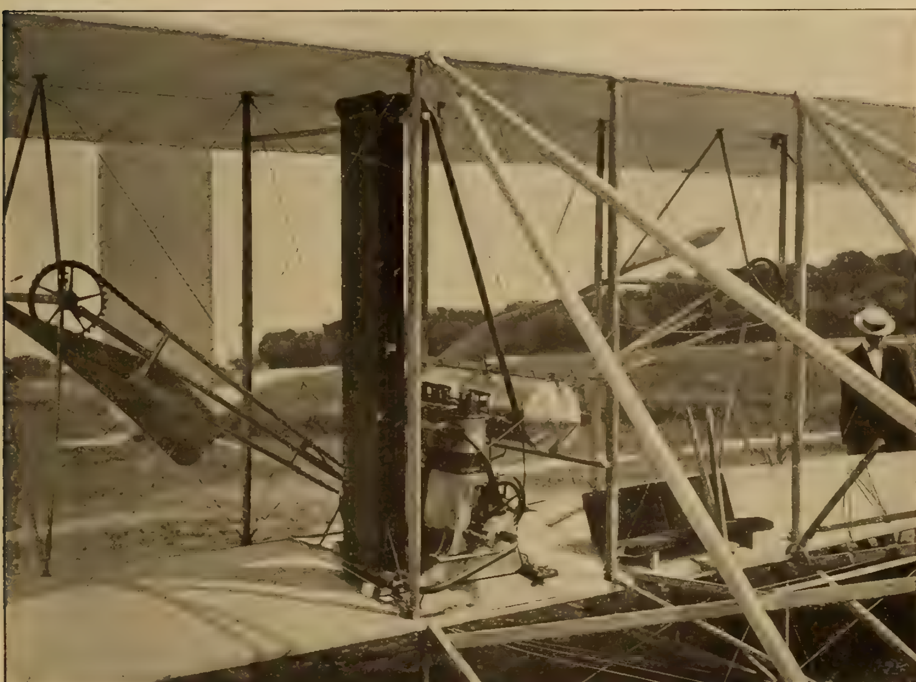
The important experiments in France with dirigibles, however, have been very largely due to the efforts of the Lebaudy brothers and of M. Deutsch de la Meurthe. The Lebaudy brothers employed M. Julliot, engineer of their sugar refinery, and M. Surcouf, an experienced aeronaut, and in 1902 began the construction of a machine embodying improvements upon *La France*, of Renard. The gas bag, which was 56.5 metres long and 9.8 metres diameter, was stiffened by a frame of nickel-steel tubes beneath, to which frame the car was attached. Two propellers were driven by a 40 horse-power Daimler motor of the Mercedes type. After a number of fairly successful

experiments, this machine was rebuilt, and, being fitted with a Panhard-Levassor motor of 70 horsepower, was christened *La Patrie,* and was turned over to the French Government. Great hopes were developed by the success of this machine, especially as, in the improved form, she made a number of long trips, at heights of 2,500 to 3,000 feet. In November, 1907, however, after a flight from Paris to Verdun, near the German frontier, a distance of 175 miles, carrying four persons, the machine was landed, but was, unfortunately, carried away by a sudden strong wind, and, in spite of all efforts to save her, drifted off over the North Sea, and was lost off the coast of Ireland.

A second balloon was built by the French Government upon the same general plans of *La Patrie,* being somewhat larger, and with this machine, called *La République,* any number of successful trials have been made, principally with a view of ascertaining the availability of such machines for military purposes.

One of the principal difficulties experienced with the dirigible balloon has been the tendency to pitching when a certain critical speed is exceeded, and various plans have been devised to minimize this disadvantage. In the *Ville de Paris,* built as a result of experiments by M. Deutsch de la Meurthe between 1902 and 1906, the pitching action is prevented to a large extent by the addition of a number of small cylinders containing gas and attached at the rear end of the main gas bag. These cylinders act in much the same manner as the feathers upon an arrow, tending to retard the rear end of the balloon when in rapid motion, and thus holding the axis of the main gas bag nearly in the direct line of movement.

The possibilities of the dirigible balloon for warfare have naturally led to experiments by the war departments of various countries, and



DETAILS OF CONSTRUCTION. WRIGHT AEROPLANE

in Germany several such machines have been constructed. Thus, Major von Gross has designed a balloon closely following the lines of the Lebaudy machine, and two dirigibles have been made from his plans. The experiments with these have been made by the War Department, and details are not made public; but the gas bag is about 130 feet long and so that it may change its position according to variations in thrust and resistance. With a gas bag 190 feet long and 30½ feet in diameter, a 110 horse-power Daimler motor is intended to give a speed of about 22 miles per hour. A peculiarity of the Parseval machine is the use of two interior ballonets, one at each end, so that these can be inflated or emptied

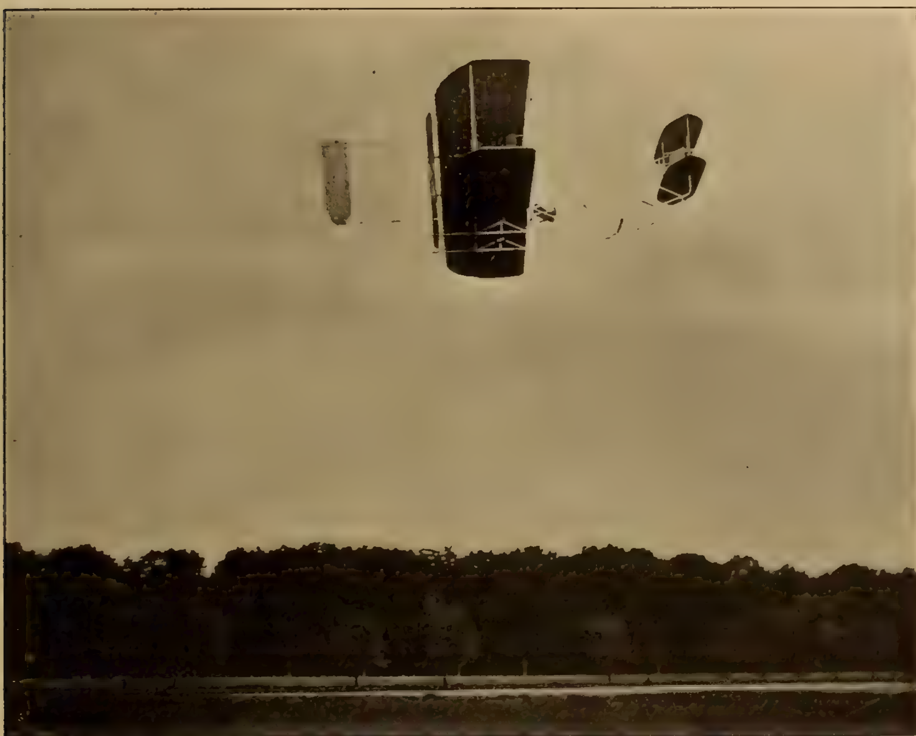
REAR VIEW OF WRIGHT AEROPLANE

40 feet in diameter, and the speed attained with two Daimler motors of 75 horse-power is about 27 miles per hour. It is stated that the Gross balloon has carried four persons for a distance of 176 miles, returning to the starting point at Berlin with entire success.

Another German dirigible balloon is that designed by Major von Parseval, this having a gas bag of cylindrical form with pointed ends, and having what is called the "loose" suspension in the place of a rigid frame. The car is carried upon two steel cables by means of four trolleys, at will. By this means the balloon can be inclined upward or downwards at will, thus causing it to act somewhat like an aeroplane.

The principal experiments made in England with dirigible balloons have been at Aldershot in connection with the work of Colonel Capper and Mr. Cody, and the special feature of the British dirigible No. 1 was the suspension, there being a stiff steel framework for the car, this being carried from the balloon both by a netting and by four wide silk bands. The propellers were placed on each side, and, driven by an Antoinette mo-

tor of 50 horse-power, gave a speed of about 16 miles per hour. The gas bag of this machine was shorter in proportion to the diameter than usual, the length being only 111½ feet for a diameter of 31½ feet. Fixed horizontal planes in the rear were used to maintain stability, and beneath these is the rudder, while movable planes in front aided in directing the vertical movements. Some successful trips were made with this machine; but it had to be cut open to prevent its being carried away in a storm in a manner similar to the *Patrie,* and further results are yet awaited.



FLIGHT OF ONE HOUR FOURTEEN MINUTES AND TWENTY SECONDS, ON SEPT. 12, 1908. WRIGHT AEROPLANE

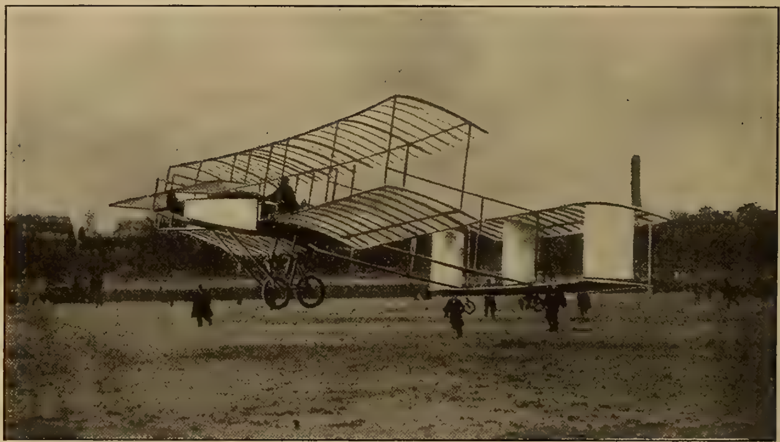
In the United States experiments have been conducted by the Signal Corps of the United States Army, a small dirigible, 96 feet long and 19½ feet in diameter, having been constructed and fitted with a Curtiss motor of 20 horse-power. This balloon is being used principally for training purposes, and it is thus preparing men in case a more liberal policy of expenditure for aeronautics by the government is permitted to prevail. The Signal Corps has erected a balloon plant at Fort Omaha, Neb., including a balloon house 200 feet long, 84 feet wide and 75 feet high, together with an electrolytic plant for the production of hydrogen for inflation.

Thus it is seen that most of the recent experiments in the construction and operation of dirigibles have been due to the possible employment of such machines for military purposes, and this is doubtless due to the fact that such work involves much expense, the private experiments having been possible only to individuals of large wealth. The development of the aeroplane, however, has been almost entirely due to pri-

vate enterprise, and the best results thus far have been attained by men who have been willing not only to risk the funds required for construction, but also willing and able to acquire, by careful practice, the skill to operate the machines which they have built.

The aeroplane is practically a form of kite, the principal difference being that it flies freely in the air without any detaining cord, this lack being replaced by the action of the motor, except in the earlier gliding machines of limited range. It was by reason of experiments with such gliding machines, however, that the motor-propelled machine became a possibility; and thus it is to the work of the first successful glider, the late Otto Lilienthal, that the modern incentive is due, an incentive which has led to the successes of Langley, Delagrange, Farman, the Wright brothers, and others.

As long ago as 1893 Lilienthal, believing that some of the features of the gliding flight of birds might offer aid in the solution of the problem of mechanical flight, began a series of experiments, using a variety of curved wings, and making his start from a small tower on a hill near Steglitz. The wings used by Lilienthal had a spread of 23 feet and a breadth of 8.2 feet, giving an area of about 151 square feet, allowing for the rounding of the ends, the total weight of the apparatus being about 44 pounds, which, added to his own weight of 176 pounds, gave a total of 220 pounds to be supported. By making judicious use of the movement of the wind, many successful gliding flights were made with this apparatus, the maximum distance covered being about 1,200 feet. Lilienthal was making experiments leading to the application of a motor to his machine, but without success, when, unfortunately, he met with a fall which caused his untimely death.



HENRY FARMAN'S AEROPLANE

The gliding experiments of Lilienthal were imitated by Pilcher, in England, and by Octave Chanute, in the United States, and the advantages of acquiring control of balancing thus fully demonstrated. About the time of the death of Lilienthal, in 1896, the brothers Wilbur and Orville Wright began experimenting with a gliding machine of their own construction, following along the lines both of Lilienthal and of Chanute, and by 1902 they were making gliding flights of 600 feet, their experiments being made on the sea coast of North Carolina, at Kill-Devil Hill. The results of these ex-

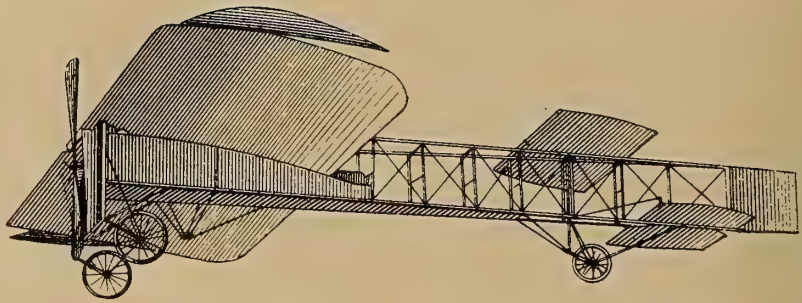
periments led to the revision of the tables of the supporting power of planes as compiled by the French Academy and by Lilienthal and Langley. By 1903 the Wright brothers were experimenting with a motor applied to their aeroplane, since which time they have made rapid progress, so that in the latter part of 1908 they were making successful demonstrations before the United States Government at Fort Myer and before French investigators at Le Mans, with flights exceeding two hours in duration, at speeds of 40 miles per hour.

In France, Farman, using an aeroplane of the box kite type, has made flights of more than a kilometre, at a speed of about 28 miles per hour, and M. Blériot has covered a distance of 14 kilometres with a velocity of 52 miles an hour.

It is thus evident that the present rapid development, both of the dirigible and the aeroplane, is almost wholly due to the progress which has been made in the production of powerful motors of light weight. The dirigible of Renard, constructed twenty-five years ago, might well compete with any of the modern machines, simply by the substitution of the motor of an automobile for the heavy battery and electric motor which the earlier experimenters were compelled to use. In like manner the successful aeroplane of the Wright brothers differs but slightly from their gliding machine, with the addition of the motor, and the machines of the French experimenters are really modified box kites with motors added.

The demand for light and powerful internal-combustion motors for aeronautical purposes has led to the production of some ingenious designs, these involving especial care in the selection and distribution of material, together with certainty and uniformity of operation. The ordinary stationary combustion engine weighs from 400 to 600 pounds per horse-power, and, while this has been cut down to 15 to 20 pounds per horse-power in the engines designed for automobiles and motor boats, the engines for dirigible balloons and aeroplanes have been constructed of weights as low as 2½ to 5 pounds per horse-power.

THE JUNE BUG IN FLIGHT AT RACE TRACK, HAMMONDSPORT, N. Y.
In February a similar machine called the Silver Dart made a flight of four and a half miles near Baddeck, N. S. The Aerial Experiment Association.



BLÉRIOT'S AEROPLANE

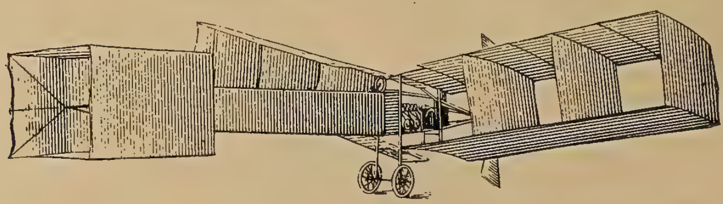
The actual weight of the machine forms but one of the elements in the reduction of the total weight to be carried in aerial navigation, since the weight of the fuel, especially for flights of long duration, forms a feature of nearly equal importance. It is estimated that a motor of 100 horse-power, weighing, say, 2 kilogrammes, or about 4½ pounds per horse-power, or 450 pounds total, will consume about 27 kilogrammes of gasoline per hour; that is, about 60 pounds; and hence a flight of between seven and eight hours' duration would require a weight of fuel as great as that of the engine itself, at least at the start, although the continual consumption of the gasoline would make the burden from this cause a diminishing one.

In considering the power required for an aeronautical motor, the reduction in the power of a combustion engine with increase in altitude must be taken into account, especially in the case of dirigibles, since these are likely to fly much higher than aeroplanes. The influence of altitude upon power will be seen when it is realized that an elevation of 3,000 feet reduces the power about 15 per cent., while at 6,000 feet the power of a combustion motor is about 25 per cent. less than what it would be at sea level.

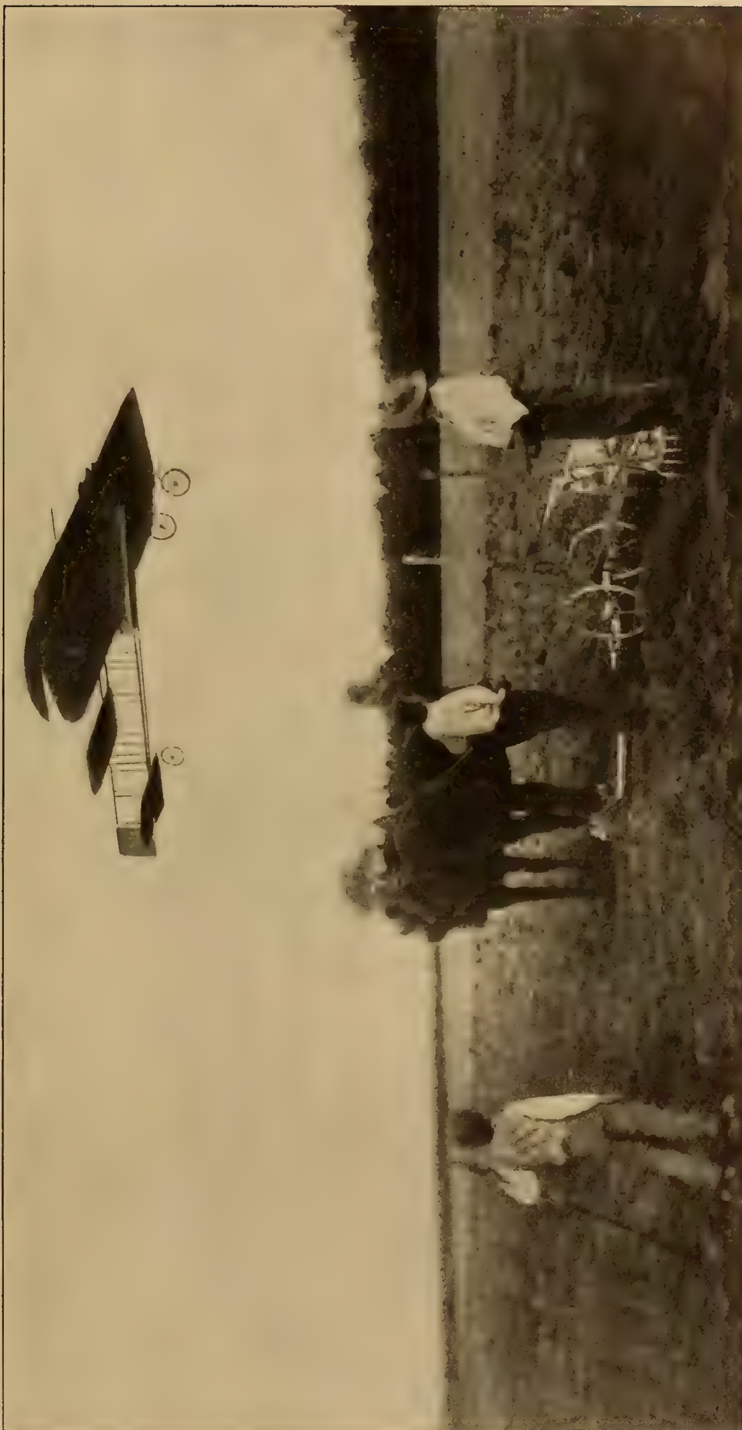
The motors at present used in aeronautical experiments may be divided into three classes, namely, light-weight automobile motors, motors for dirigibles, and specially light motors for aeroplanes.

The German dirigible balloons have found the engines designed for the highest class of automobiles well adapted for their service, and examples of such machines are seen in the Daimler engine, of 100 horse-power, two or three of which are used in the dirigible balloons of Von Zeppelin, as well as in the balloon of Major von Parseval. This motor is practically the same as is employed in the well-known Mercedes car, and has four cylinders, cast in pairs, the inlet valves being in the cylinder heads and the exhaust valves on the side.

The latest balloon of von Parseval is equipped with an engine of



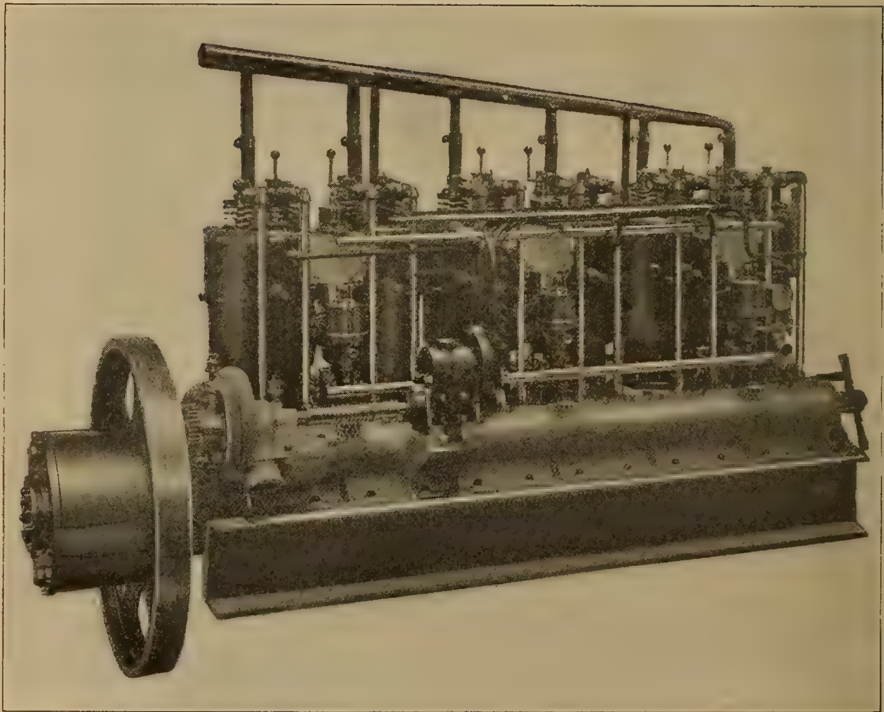
AEROPLANE DESIGNED BY SANTOS-DUMONT



FROM TOWN TO TOWN BY AEROPLANE. MR. BLÉRIOT FLYING OVER A FARM DURING HIS FLIGHT FROM TOURY TO ARTENAY, FRANCE

the Neuen Automobilgesellschaft, this having six cylinders and provided with three carburetors, so that if either carburetor or a cylinder should fail for any reason to work it may be cut out and the engine continue to run with reduced power. Motors of this type weigh about 4 kilograms, or 8.8 pounds per horse-power. Another engine of similar character is that built by the Eisenach Automobile Works, this motor having all the valves on one side, and being provided with radiator and fan similar to the arrangement of the Daimler engine. An important feature in any such motor for aerial service lies in provision for the oscillation of the car and consequent inclination of the engine. The arrangement for lubrication in the crank case in the ordinary engine is not wholly effective when the engine is inclined, since the oil flows to one side, leaving the other side dry. It has been found advisable to provide additional sight lubrication to meet this condition, and this feature should not be overlooked.

If lighter weights are required than can be found in existing automobile engines, it is necessary to resort to specially designed motors. An example of such an engine is seen in the 8-cylinder motor, of 72 horse-power, built by Messrs. Körting for the German military air-ship built according to the plans of Major von Gross. This engine has the cylinders arranged at an angle of 90 degrees, the cylinders having a bore of 116 millimetres and stroke of 126 millimetres (4.5 inches by 5 inches), and developing 72 horsepower at 1,400 revolutions per minute. This engine consumes 21 kilogrammes of benzine per hour (46.3 pounds) and 1.4 kilogrammes of lubricating oil (3 pounds), and the total weight of the engine is 200

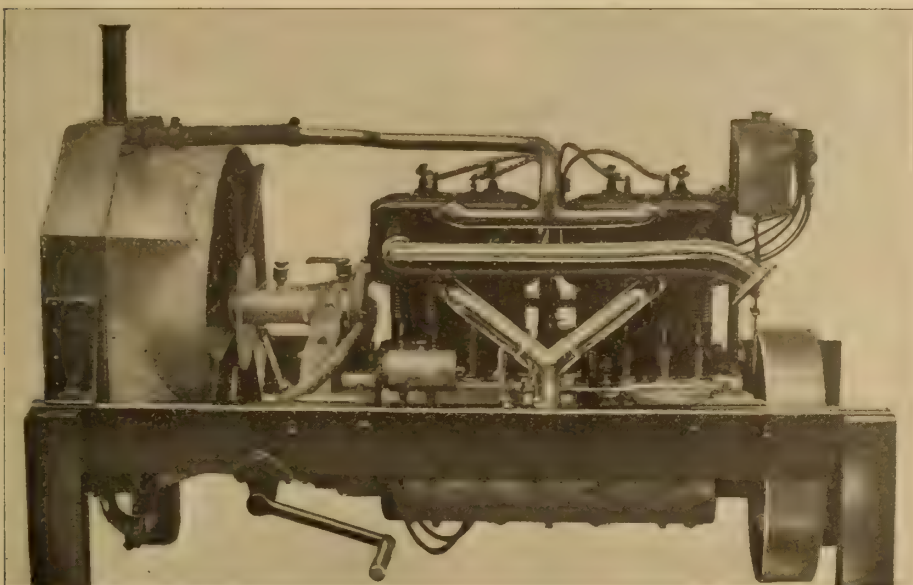


100-H. P. AIRSHIP MOTOR BUILT BY THE NEUEN AUTOMOBILGESELLSCHAFT

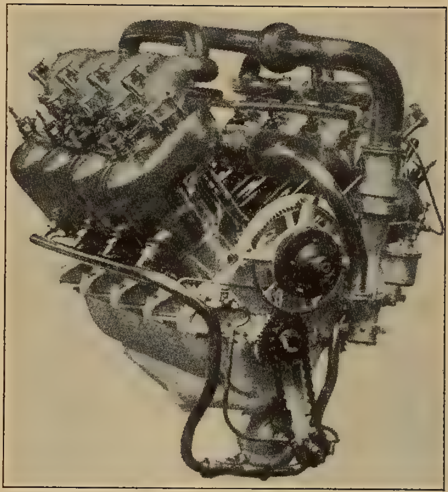
kilogrammes, or about 3 kilogrammes (6.6 pounds) per horse-power.

The lighter motors, designed for use with aeroplanes, include the Antoinette motor, used in the machines of Farman and of Delagrange, this engine having been especially designed by Levavasseur for the attainment of high power with minimum weight. The Antoinette motor is constructed with cylinders inclined at an angle of 45 degrees, the number ranging from eight to as many as twenty-four, and the weight being as low as 1.5 to 2 kilogrammes per horse-power (3.3 to 6.6 pounds). The 50 horse-power Antoinette machine made for Farman has eight cylinders and the gasoline is injected directly into the cylinder, thus dispensing with the complication and uncertainty of the carburetor.

Another light-weight French motor is that made by Rénault Frères, of Billancourt, this also having eight cylinders, placed in inclined position. The Renault motor has no water circulation, but is air-cooled, the cylinders having ribbed exterior surfaces. A motor of this design, developing 42 horse-power, weighs 130 kilogrammes, or about 3 kilogrammes (6.6 pounds) per horse-power. Among the French engineers, M. Esnault-Pelterie has applied strict scientific principles to the designing of a light-weight, high-power engine. The true principle underlying the construction of a motor of light weight is to equalize the stresses as much as possible. The rupture of any part of a machine is brought about by the maximum stress to which it is subjected, and in engines of the internal-combustion type there is ordinarily a great inequality in stresses, the instant of explosion necessarily bringing the heaviest shock upon the working parts. By multiplying the cylinders and arranging them around the shaft, it is possible to substitute a number of impulses of moderate force for fewer efforts of greater magnitude, and it is easy to perceive that, with a very large number of small cylinders, a turning moment of almost uniform effort might be substituted for the few and sudden impulses of the ordinary explosion mo-



AIRSHIP MOTOR BUILT BY THE FAHRZEUGFABRIK EISENACH



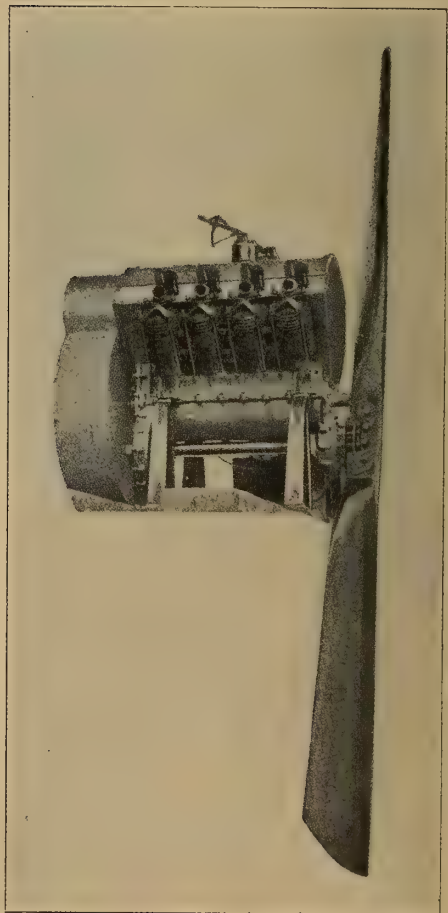
72-H. P. AIRSHIP MOTOR BUILT BY GEBRÜDER KÖRTING

tor. Such an arrangement would greatly relieve the stresses upon the various parts of the machine, and thus permit a reduction in weight by allowing a reduction in the section of the different members; and it is upon this principle that M. Esnault-Pelterie has proceeded. As a result, he has produced an engine of 35 horse-power, which weighs only 114 pounds, or about 3¼ pounds per horse-power, one of the lightest yet constructed.

An entirely different type of motor is that in which the cylinders themselves revolve about the shaft, of which an example is the engine of Bucherer, of Elberfeld. A similar machine, except that the cylinders revolve in a horizontal instead of a vertical plane, is the Adams-Farwell engine, this having a weight of only about 100 pounds for an engine of 36 horse-power, or 2.8 pounds per horse-power.

In view of what has been said about the relative importance of the weight of the motor and of the fuel, it is evident that, for long-distance flights, the fuel economy of the engine takes on an increasing importance over its gross weight, and the present tendency is to consider that the extreme lightness of some of the motors is not absolutely essential.

Above all things, reliability is essential in a motor of aerial service, especially for aeroplanes, in which the operation of the engine is essential to the maintenance of the machine in the air. Although a properly constructed aeroplane will not fall, but will descend gradually if the motor stops, it is altogether possible that the machine may be over water, or above a densely wooded country, or, in case of war, may be inconveniently close to the enemy, and the continuous operation of the motor thus becomes indispensable to the safety of the operator. For these, and similar reasons, it is now generally accepted

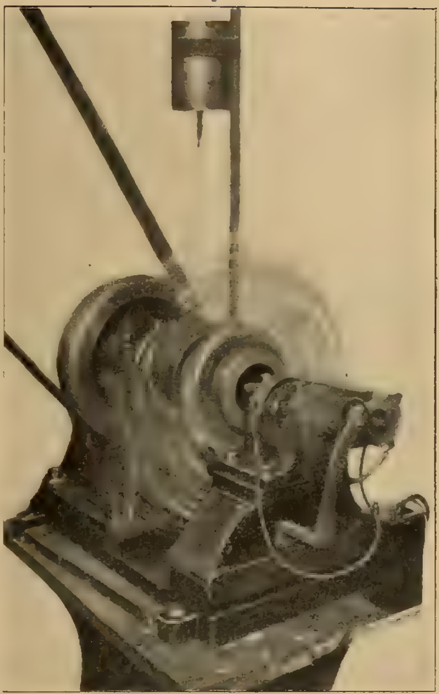


42-H. P. AEROPLANE MOTOR BUILT BY RENAULT FRÈRES, BILLANCOURT

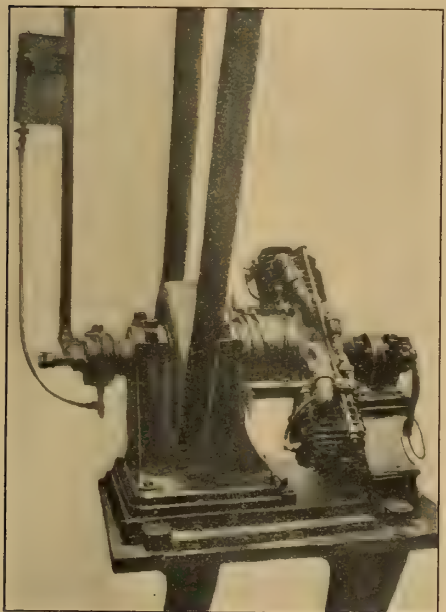
that there is no further reason for attempts to attain greater lightness; but that maximum reliability, simplicity and a high degree of economy in fuel consumption are the ends to be secured.

The experimental work which has been conducted with the gas turbine has not yet progressed sufficiently far to warrant any assertions about motors of such types for aerial service; but it is evident that a motor operating at high rotative speed with a continuous impulse, if of sufficiently high efficiency, would be the ideal source of power for both dirigibles and aeroplanes.

So far as future developments are concerned, it is impossible to make any predictions, but some of the limitations which have thus far been encountered may be mentioned.



THE SAME MOTOR IN OPERATION



AEROPLANE MOTOR WITH REVOLVING CYLINDERS, BUCHERER, ELBERFELD

Both with the dirigible and the aeroplane, the limit of controlled flight is dependent upon the rate of fuel consumption, and the supply which can be carried. With large machines, such as the Zeppelin, or the French military balloons, the requirement of 24 hours' continuous flight indicates the present cruising ranges, so to speak, of such machines. The practical results with the Wright aeroplane, with more than two hours' sustained flight, show that such machines already have a fair range, but the fact that machines of this type are dependent upon their motion for their support renders the continuity of operation of the motor is especially important in their construction.

The limits of size of aeroplanes of ordinary construction are governed by the fact that the sustaining power increases less rapidly than the weight, but by using the tetrahedral construction of Dr. Alexander Graham Bell, this difficulty may be overcome, and thus we may see aeroplanes large enough to compare, in point of carrying capacity, with the larger dirigibles.

SOME SUGGESTIONS OF REFORM IN ENGINEERING PRACTICE

II.—INDUSTRIAL AND ADMINISTRATIVE

By J. E. Livermore

SOME time ago I contributed to CASSIER'S MAGAZINE some notes on "Industrial America," and one point I touched on which I propose to deal with again, viz., the working hours of some of the English shops and factories as compared with those in America. Our method is in my opinion not suited to present-day requirements, and it is time we had a round-table discussion to fix these hours and arrive at some kind of a uniform standard for working hours and meal times which shall apply to all shops and factories in the country. Our present arrangement has many drawbacks, and I believe is the cause of much lost time to a number of people who are not directly connected with the various works.

Suppose we consider the morning start. Some works commence at 6 o'clock, some at 7 o'clock, some at 8 o'clock. The last two most likely obviate a stoppage for breakfast, and, as far as the morning is concerned, they show an advantage. But what about the 6 o'clock start? That is an institution which I believe could be wiped out with advantage. I believe some changes have been tried in various parts of the country, but it is strange that where there are the largest number of workmen they still hold to the 6 o'clock start. Yet there are several things which seem to point to the fact that the 6 o'clock rule is not the best. First there is always a tendency to oversleep, which is proof that the man is not (from Nature's point of view) ready for work. Thousands of men are awakened from a sound sleep by the "knocker up," who does his best to make the small hours of the morning hideous. What does this going to work at six o'clock mean? Many go without a scrap of food or drink and work from 6 o'clock to 8 o'clock or 8.30 o'clock before they get any breakfast. Is it to be wondered at if a man kills time before breakfast as much as possible? Again large numbers of men just have time to snatch a cup of coffee and take a bite of food before going into the works. If that is necessary to keep them up, would it not be better to get up, say, at 6.30 instead of 5.30, have half an hour for a proper breakfast and then make a start?

I fail to find economy in the 6 o'clock start, and I should not be surprised to find that a vast majority of the work done before breakfast shows a loss compared with that done in other parts of the day. This time question is vital in other respects, and employers ought to seriously consider some means of changing it. The question is not entirely a workman's question, but in a change of this kind their cooperation is necessary. Taking the morning hour from 6 o'clock to 7 o'clock there is one complete hour that might be saved in light alone, which in a large works would mean a considerable saving at the end of the year, assuming, of course, that the works are not employed both night and day. Then, again, the 6 o'clock rule is generally in force in shops where the men have most quarters off in the morning. This is quite sufficient to produce a heavy charge on machines standing idle, which, under proper working conditions, would not occur. It pro-

longs the time required to produce a finished article, and consequently hinders delivery; this lost time has to be taken into account when estimating, and extra time for delivery is required. Is it possible that the workmen realize all this; if not, then it is time they were told. These early morning working hours do, as a rule, represent the time when least work is done, simply because your man is not in a fit state of efficiency; he drags along very much like a steam engine whose steam pressure has dropped 15 or 20 pounds owing to lack of firing.

But the trouble does not stop here. The difference in the time of beginning work in the morning changes the breakfast time, and also the dinner time. It is no uncommon thing to see in a town men going to dinner at 12 o'clock, 12.30 and 1 o'clock. A traveler calling on a firm, say, at 12 o'clock, finds them closed for dinner; it is important that he should do his business and maybe he will wait till the works commence again. Now by the time he has finished his business and gets to his next place, they, too, have gone to dinner, because they stop at 1 o'clock, and so the loss of time goes on. Again, the loss does not finish with the traveler. There is always to be seen in English towns a large number of railway vans delivering and collecting goods. Frequently they arrive at a place just as the men go to dinner and have to wait an hour before they can unload or deliver a particular case; and when they move on again and reach the next place the same thing happens again, and so the loss goes on and goods are hindered in delivery and collection. Any day in London scores of railway vans can be seen waiting to load or unload at various works just between the hours of 12 o'clock and 2 o'clock; while it may not be possible to prevent all this, a very great deal of it is due to the way in which our working hours are divided up.

I am absolutely in favour of the American way of dividing up the day, which is this: Breakfast first, begin work at 7 o'clock, dinner 12 to 1 o'clock, and stop work at 5.30 o'clock. In practically all works this arrangement is understood, and the traveler, the carman, and the railway company, and, in fact, the whole of the town know this time and arrange accordingly. They look upon it as a system, and of its benefit there is no doubt. The "Daylight Bill" recently introduced into Parliament certainly had its good points and received considerable support. In brief, it was an arrangement whereby you got up at 6 o'clock and made yourself believe you were getting up at 7 o'clock, so as to make use of more of the daylight. That was a good idea, but on the face of it, it is difficult to understand why this bill should have taken up the time of the House of Commons and gained adherents all over the country, while we have a deplorable waste of time in another direction going on. I for one refuse to believe that the present system is the best, or that a remedy cannot be found. When you are sure of your working times and your meal time, and a uniform system prevails, arrangements can be made to the best advantage all round, but with our present confused method proper arrangements are out of the question.

It is, perhaps, difficult to say to what extent these things affect business; that they do affect it there is no doubt, and one could go on citing examples for a long time. I have only taken a few which I think are more pronounced than some others.

The next point, I think, is one that can be looked to with advantage, and that is the finish of some of our manufactured products, but especially machine tools. Finish has a commercial value, and the sooner we realize that fact the better we shall be for it. And we must realize, too, that the term "finish" is to be ap-

plied in a broad, general way. It does not necessarily mean that the particular article shall be polished and look pretty. A machine can be produced which is powerful, well made and, at the same time, symmetrical; we want the symmetry of design to be sufficiently marked to arrest the attention of prospective buyers; having secured that, we can then proceed to show up the other good points. I doubt if any country has ever put the value of finish more to the front than American machine tool builders. Whatever may be said for or against their machines, they are invariably so designed and finished as to create a very pleasing effect, whereas some of the machines of English build are distinctly lacking in that respect. Greater attention, however, is being given to this point than was the case four or five years ago, and there is no doubt that those firms which have borne it in mind have reaped an advantage. Of course, the question may be argued. The builder may say, "My machine does the work all right, and, after all, finish does not earn any dividend." With that I do not agree. Machine tool builders make machines to sell as well as to use themselves, and what may be considered good finish for their own use is not necessarily good in the open market where they sell in competition with an article of high-class finish.

We have yet to realize the value of the grinding machine in finishing work. There are still a lot of parts which are not revolving shafts, but which could be very much better finished by grinding than they could by emery cloth and brute force. The polish on outside bright pieces cannot be compared with the even and regular finish which is put on by the grinding machine. When a piece of work is finished in the lathe with emery cloth, there is always after turning a number of lines—or should I say small grooves?—which appear on the surface. These at once disappear when the machine finish is introduced. In certain parts of machine tools there is always a number of pieces which are divided and marked in degrees, fractions of inches, and so forth; it is noticeable on many machines how rough this dividing is, and there is no doubt that it is due mainly to an improper method of preparing the part for indexing and dividing, and to finishing it after the dividing is completed. Consider for a moment a circular piece of cast iron divided into degrees on its periphery. Now this is often done just as it leaves the lathe, and it is almost sure to be more or less out of round; consequently at some point the divisions are cut slightly deeper, and the line is wider here than at other points, and the difference is plainly seen, Now if the article is not well finished the lines show a broken, ragged edge, which looks bad, and there is also the question of slight inaccuracy; where this dividing is an important part of a machine it requires the same good attention to make it correct as do other matters.

Suppose now we grind the periphery of that piece of cast iron and make it perfectly smooth and round and leave it, say, 0.003 inch above the finished size. When we have done this, let the piece be divided into degrees, or whatever is required, and when that is finished, go over the piece again with the grinding machine and remove the remaining 0.003 inch. This will be just enough to remove the ragged edges and will leave a perfectly clear line of uniform depth, which will have a good effect. The same applies to small tools which can be stamped and are not hardened all over, such as drills, reamers, taps, etc.; all these little things help toward making a more perfect whole. Of course, it may be said that this means two grinding operations. But what of that? It pays the American tool builders, whose labour costs are higher per man than ours; would it not, therefore, pay us? In one well-known

shop in America the firm have standardized the slot in the screw heads they use, and have also standardized the screwdriver; consequently they fit the slot perfectly, the screws go home tight, and, as the end of the screwdriver is square and not wedge-shaped, there is no slipping out and no damage to the screw heads. This is a simple thing; yet it pays, and is all a part of one great scheme which makes for all-round efficiency. In view of this it is difficult to believe there is no value in finish.

A very noticeable feature of machine tools now is the arrangement of various mechanical sections, each separate in itself, but the whole forming a complete machine. Each of these units is guarded by a neat cover which is often a really good casting, and one on which a deal of money has been spent. This expenditure has been chiefly made on the pattern, with the idea of making a fine casting of high-class finish. It is in a number of cases machined and fitted, and even doweled; it is finally held by cheese head screws, which are countersunk even with the casting; this is also applied to other guards covering moving parts.

Compare this neatness of finish with a rough made guard or casting, held in position with a square head screw, with which it is quite impossible to make any kind of a decent finish. With a rough exterior appearance it is very difficult to convince a likely buyer that other parts are fully up to the standard required for a high-class machine.

In order to save a little expense in fitting you damage the appearance of the machine, and do your best to make it look like cheap goods. Finish is worth £ s. d., and to neglect it is to lose money.

In these notes I have touched on a number of points which, I believe, affect the well being of certain classes of engineering work. These points are chiefly connected with the method of manufacture and costs, but now I want to say something about the small manufacturer and the shop in which he carries on his business. There is generally found in large towns a good proportion of men who have small manufacturing businesses. They are producing an article which is often in a class by itself; they have not a world-wide trade; the business is one that employs a few dozen hands and makes what is called a living profit. London, in particular, is a town which has a large number of such firms. The desire of every business man is to get the best position and the most suitable premises in which to carry on his business, consistent with reasonable cost. One thing which has to be taken into account with many of these firms is, that they do undoubtedly find it an advantage to have their business premises in the neighbourhood where their name is well known. It is noticeable how old and ill fitted for manufacturing many of these small workshops are. One finds in some districts quite a small manufacturing establishment being carried on in what is neither more nor less than a cellar; others make use of a "single" floor, generally an attic. Now all these places may be useful for some class of work, but when it is a question of using machine tools for producing manufactured goods this class of workshop can only be described as bad.

The principal entrance is generally by a dirty, badly lighted staircase; the building is old and does not lend itself to healthy conditions for the workers. There is a regrettable absence of light and ventilation, and office accommodation is strictly limited. But this is not all; the address of these places is generally up a lane, an alley, or a side-street, very often in an un-get-at-able place, where you cannot hurry; one van cannot pass another, and in some cases, when a van is drawn up at the works, it can only return by backing out. Possibly, when we get a flying machine that will soar,

the delivery of goods may be more speedily effected under such conditions. These places are troublesome to find; people coming to them on business lose time in finding them; many of them are not shown on the map, and a person calling, often goes away with the fixed intention of not going to that place again if it can be avoided. The business of to-day cannot be successfully run under these adverse conditions. A firm must have its name to the front, and it is high time that some steps were taken to help these small industries out of their present unenviable position.

When a row of dwelling houses become unfit for habitation, they seem to be regarded as suitable for workshops, and, what is more strange, there is always a tenant to be found. Rents are high in London, so they are in other large towns, and we want a place as cheap as possible, but it will pay to ask ourselves whether these places are really cheap. The landlord tells you the ground is valuable, and he naturally wants the highest rent he can get. Then you have your rates and taxes to pay in proportion, and your fire insurance rates are high on all this class of property. There is a loss of time in nearly every way, and there is a further loss, due to your business being hid away. It may be all right for those who know you, but what about new business? Is this to be neglected? Taking a broad view of the question there is no doubt that these places are dear at any price. I should like to compare this class of shop with what I have seen in American towns, but here let me say that America is not entirely free from these drawbacks. Recently, however, a move has been made in that country which we might very well follow up with advantage: this is the introduction of what is called the "Manufacturers' Building."

This building is generally erected by a limited company, and let out in sections to suit various manufacturing concerns. Of its advantage there is no doubt whatever. Imagine a big square building so arranged that the centre forms a good-sized yard. This building is arranged with an entrance on each side for the heads of the firms and those calling on business. On one side, adjoining the main street, is the entrance into the yard for workpeople and goods. This building is specially built for small manufacturers who do not want a large works, but who require modern conditions to carry on their business. With a building of this kind less area is taken up by a number of works if a series of separate buildings is used for the latter. In choosing a site for premises of this kind it is the aim of the company to get the best all-round position. Such a condition can be obtained when one is putting up a place quite easily made both useful and artistic.

The place chosen is generally near to the railway and station, and close to the business centre of the town. Being a place of some importance it is easily found; everybody knows it. It is not placed in a back street or hidden away; it is generally approached by a main street. The building proper is generally of a heavy, substantial kind, and is some six or seven stories high; each floor is of fireproof construction and is quite self-contained. The floors are so arranged that every firm hiring a portion for a workshop can have a proper space to be used for office purposes. A number of passenger elevators afford a rapid and easy means of reaching each floor. The shop can be divided into departments, and when space is hired suitable partitions can be erected to suit the particular shops.

By having the middle of the building open, there is a good supply of daylight and ventilation; the shops are cool in the summer and comfortable in the winter. On each landing there is provided lavatory

accommodation for office staff and workpeople, with hot and cold-water supply. In these buildings in America a part of the yard is taken up with boilers and engines. Here is installed the plant for heating, either by steam or hot air, and coupled to the engine is a generator for supplying electric light and power, also air compressor, if necessary, for pneumatic tools. Inside the yard are one or two heavy types of elevators for conveying goods to and from the various floors. This allows of more than one van to discharge at a time, and you do not get carmen, with all kinds of things, tramping through the office. As far as I can remember, the premises are hired on the following system: You pay a certain sum for space; this includes heating, hot and cold-water supply, care of lavatory, watchmen, elevator attendants, all rates and taxes, and letter boxes inside the building. Thus the occupier has three charges—namely, rent, electricity charges and fire insurance; and, taken as a whole, these amounts come out at a lower charge than when old, independent premises. Possibly, in an English town, where there are already existing electricity supply companies, some objection might be raised to the owner of the building supplying power and light to a number of firms, but this could be met by the company who supplied the district being allowed to supply current for the building for all purposes, and would be cheaper, perhaps, than generating it on the premises.

I consider the advantages of a building of this kind are such that in a place like London and other big towns it would be a success. By such means you would put the small manufacturer in touch with conditions which are out of the question in old buildings. He would have a first-class workshop and proper offices; his employees would work under healthy conditions; his fire risk would be reduced; he would have a lift attendant and a watchman; his sanitary arrangements would be perfect, his place of business central; he would be near the railway and would have a good address easy to find; his works would not be hidden, and it would be within the limits of possibility to have a telephone exchange within the building. In short, such a plan gives all the advantages enjoyed by a large works at a less risk and worry, and, I fancy, at an expense which is less than that of carrying on business in a tumble-down place.

It is generally the rule now in most towns to put up large blocks of office buildings. These are equipped with all modern improvements, such as elevators, electric light, also attendants and watchmen, and there is no doubt of the advantage of this. It surely does not need much of a philosopher to see that if these office blocks are a success, there is no reason why the same arrangement applied to manufacturing should not be equally successful. Here you have a number of factories with practically one address. Consider for a moment what it means to a railway company delivering and collecting goods? They can go straight to the spot, deliver a load and return with one. There is not one-half the time taken, or perhaps I should say wasted, that there is with our present method of dragging up and down narrow streets, blocking the road and running up expenses in lost time, to say nothing of delivering goods half a day late. You who buy the goods have to pay delivery either direct or indirect, and it is to your advantage to cut down delivery expenses by improving the methods employed. The same applies to letters; you deliver Smith's correspondence at the same time as Jones', and both are delivered early.

I have spent some time in a building of this kind and have had an opportunity of noting the way it

is worked, and I am fully convinced of its value. London, with all its small manufacturers, its crowded streets, and need for centralization, is a place where the manufacturers' building is badly needed. The workshop of the small manufacturer must be considered along with the larger manufacturer. We want both to be equally prosperous. If the average landlord does not see that the premises he has to offer are behind the times, then some one must make it clear to him. We have reached a point where we can no longer disregard a business because it is small. Trade must not be determined by the size and style of the building and plant, but rather the plant and building must be suited to the business.

I consider that the time is ripe for a building scheme of this kind to be discussed, so that we may ascertain what the chances of success are likely to be. With this in view, I would suggest that small manufacturers, railway managers, architects, builders, electricity supply companies, and all persons interested be asked to consider the scheme, and, if possible, to call a meeting and further discuss the subject. In the concluding part of these articles I want to say something about foreign trade and the way some of it is done. I do not intend these remarks to apply to those firms who are manufacturers, and who conduct their foreign trade by sending their own representatives abroad; such methods are to be highly commended, and it is a pity that there are not more English firms who can do likewise. The foreign trade we are concerned with here is that which is done by the shipping firms who receive from their agents abroad requests to purchase certain articles and ship them to the party named in the request. It is perhaps difficult for the mechanic to take the same view of this shipping business as the shipper himself would. For several years now I have come into contact with shipping firms who, from time to time, send out inquiries for machine tools. Since this is the branch of engineering I am concerned with, I propose to consider that branch in relation to foreign trade.

I have come to take certain things in connection with shipping as hard-and-fast rules. Briefly stated they are as follows: Any kind of lathe seems to be known as "a lathe," simply, any kind of milling machine as "a milling machine." This same applies to drilling machines, and in fact to most machine tools. The chief thing which is considered appears to be low first cost, while quotations and all written matters must be so arranged that the shippers take no risk. I do not know who is to be blamed for this state of affairs, but it seems to me that the whole question is one that could be vastly improved upon for all concerned. Where shipping houses have a trade that consists in buying and selling machinery, it is a certainty that they must employ someone with technical knowledge, otherwise that part of the business is neglected.

It is, of course, necessary to have a buyer to attend to the purchase of all goods, but I fail to see how a man can buy to the best advantage when he does not understand fully the article he is buying. There are firms who have realized this point and have found it to their advantage to engage an engineer who attends to these mechanical matters, and who inspects and reports on all machines that are bought. He also gets up full particulars, classes them out, and then leaves the buyer to make the best terms possible. This method is all right and good results will come of it, but to expect a buyer to sort over all this matter and give opinions on such things as machine-shop operations, and compare the relative value of the milling machine with that of the planing machine on any particular operation, or state an opinion on the value of

various cutting tools made in different brands of steel, seems to me to be only wasting time; yet this is a matter of everyday occurrence. Such questions are put to the engineer traveler every day of his life, and he is expected not to make guesses, but to give a definite, common-sense statement, and most likely on that statement will depend whether he takes an order or not.

Take the head of a firm here in England buying a machine tool, and then look at the way machine tools are bought by shippers for abroad. The man in England receives a quantity of particulars of certain machines which he thinks likely to suit him. He will carefully weigh up all the points mentioned for each machine; he will consider the kind of labour required to operate the machine, the tool equipment and its cost, and he will probably finish up by asking for a guaranteed production of a certain number of pieces in a given time and stipulate the limit of error allowed. Competition is keen and he cannot afford to take chances. I think it is safe to say that, while many firms of engineers have a buyer, there is not one who would expect him to be the man to carefully consider these various technical points; he is, in fact, as his name indicates, the buyer, and that only. He buys only after he has consulted those who are in charge of the mechanical end of the business, and who are competent to offer advice. He has found out what is wanted, and having done that he proceeds to make the best bargain possible. Now about the shipper who has no adviser to help him in these matters, but who undertakes to purchase just the same kind of article. In the various ports he has his regular agents. These good people are asked to obtain, say, a lathe. They send home to the shipper the inquiry, and, as expected, they are not able to ask for what they want, simply because they do not understand what it is. Frequently in foreign countries the person who will actually use the lathe does not know what is on the home market, and it often happens that he asks for something which has become obsolete. In due time the inquiry reaches the shipper and, however good may be his intentions, he cannot say more than has been said to him by his agent. The usual inquiry begins of a number of firms who make and sell lathes. The letter generally reads something like this: "Dear Sir, Please quote us by return your best price, with utmost discounts for shipment for one 10-inch lathe, delivered F.O.B., etc." That is a fair sample of what the agent has sent perhaps ten thousand miles, and it does not call for any special effort on his part to write it. The most interesting thing about it is that he wants a reply by return mail. I submit that such an inquiry is a farce, that there is no trace of business reasoning in it, and also that with such a limited quantity of information it is impossible to buy or sell to the best advantage. The height of absurdity is reached, however, when the inquiry asks for automatic machines. By some strange coincidence, shipping firms seem to get hold of more inquiries for automatic machines than for any other kind, yet the conditions which have to be taken into account with automatics are, as a rule, more numerous and complicated than with plain machine tools, and the inquiries which are sent out asking for this class of machine are really too funny to warrant serious consideration. To handle them properly one would have to be an expert in thought transmission. I beg to submit two specimens which are not uncommon cases: "Dear Sir, Please quote us your best price, with utmost discounts for one automatic machine, which will enable us to cut all kinds of gear wheels, etc."; and, again: "Dear Sir, We have an inquiry from our friends for automatic machines

to produce about 5 tons of screws and bolts per week. We shall be glad to receive your best prices, etc." It would, of course, be possible to hunt out the necessary particulars to quote for both these items, but it is a big task; it generally ends in your writing all sorts of particulars and setting the inquiry in order, after which some enterprising man on the spot books the order. Consequently such inquiries are treated rather lightly because they do not convey sufficient information to enable them to be dealt with properly. Yet, if we read them between the lines, I say they convey a very large amount of information, and I would like to ask if we are making use of that information. Let us see. Considering the nature of these inquiries it is necessary to get a good deal of detailed particulars. When you call on the shipping firm who sent you the inquiry you are received and treated as a gentleman, and wherever information can be given it is always forthcoming. You find a clerk whose politeness at times is quite embarrassing, and he will listen attentively to any suggestion you make, but, unfortunately, he has handed on the enquiry as they (his firm) received it, and he regrets that he cannot give you any more particulars, and you leave the office perhaps a sadder but not a wiser man.

Evidently, then, there is something wrong here. How are we to find out? It seems difficult to blame anyone unless it is the shipper, and even under present conditions they can hardly be responsible. I believe that these inquiries can mostly be taken as genuine, but the way they are sent is due to limited knowledge of the particular subject. They cover a wide range of machine tools, which seems to be proof that these tools are required; to what extent it is at present not possible to say. The lack of definiteness in the inquiry seems to point to a want of knowledge of elementary shop terms and facts, which is more pronounced in connection with the later and more up-to-date tools; yet, at the same time, it displays a desire on the part of would-be purchasers to get what is latest and best, without knowing just how to go about it.

By the term Automatic many seem to think that because a machine is automatic it is only necessary to feed it with raw material and then remove the finished product as the machine produces it. It is looked upon as a something which reduces the labour bill; in a certain sense this may be true, but with automatic machines there are some points which it is well to carefully consider. First, we require to know what is the cost of the machine and the cost of the equipment of tools, how many pieces will the machine produce in a given time, to what accuracy are the pieces required, what kind of labour is at hand to attend to the machines, and (what is also important) whether you can be assured of a good supply of stock of the right kind. If you make pieces from bar stock, it is a vital necessity that the bar stock should be of a regular and uniform quality. You must also consider the number of machines you can keep employed. There is perhaps no gain at all by using one automatic unless your operator is a man above the average, and in foreign parts this is rarely the case, excluding, of course, America and part of Europe. Consequently you require a toolmaker and a man to set up the job and keep an eye on the machine generally, and until these points have been considered in relation to each other, it is not possible to talk about automatic machines. To judge from inquiries sent home I should say that these particulars are not always taken into account. When we come to automatic machines for cutting gears, the value of using one machine is more apparent, since a great deal depends on the accurate preparation of the blank, and also how it is

placed in position on the machine, and whether the operator can be trusted to make the necessary fine adjustment without requiring a skilled man. These are the things which determine the quality and quantity of the work. Where they are neglected, there is not the gain which might be expected. A machine of modern construction, if sold and put to work without considering these conditions, will most likely earn for itself a bad name. Added to all this, you get, by reason of the machine being automatic, a greater complication of mechanical detail; there are a certain number of separate mechanical units which go to form one complete machine; let any one of these units fail to perform the duty allotted to it, then all the rest are put out of action, and before you can get running again you must call in the skilled man. Do the agents who send home inquiries for automatic machines realize this? From my observations I should say they do not.

I believe it is within the limit of possibility to remedy this sort of thing, and I also believe that the remedy can be made profitable. In buying and selling to the agent the shipper is placed at once in the same position as the machinery merchant. Now, no merchant would think of running his business without a representative who was a mechanic as well as a salesman. He has to send these men about, because present-day requirements call for a man who is familiar with the goods he is selling and is able to talk in shop terms. If it is necessary to have a man of this kind to travel in England, how much more so is it necessary to have someone who can periodically visit the foreign agent and ascertain the needs of his district?

The number and various kinds of inquiries which come to the shipper seem to show that the following method might be adopted. Instead of leaving this class of inquiry entirely to the buyer, suppose the shipper engages the services of an engineer and enters into the business in a more practical manner, making a serious effort to secure the orders in much the same way as his competitors. Let him specialize a little, find out what his customer wants, and get it for him. It would be easy for a trained man to prepare lists of the various machines and to classify them; he would have the past transactions of the firm to guide him as to what machines were inquired for. Having got this, it ought to be possible for his firm to arrange good terms with the shipowner for a cheap rate of passage for him, seeing that it would be to their advantage to assist in making his mission successful. He would then visit the various agents and take care to introduce that particular plant which he has been at pains to procure information on. The agent in turn would help him by arranging interviews with those firms who are likely buyers of machines. In this way he would take out the latest information, and the short interview would undoubtedly do more real good than six months' letter writing. But perhaps the shipper will say, "I already have an engineer whom I keep abroad." That plan, however, is wrong, because by keeping him there you shut him off from what is new, and in a short time he becomes as helpless as the agent. He must be employed to go backwards and forwards, taking care that his home department is well primed on the latest things, so that when he is abroad and sends home instructions they will be understood, attended to quickly, and in the most effective manner. If you are going to sell, you must educate your customer and get him interested in what you have to sell. If you refuse to do this, don't complain if you lose the order. It is not good reading for the Englishman to see in his paper that there are large numbers of

ships laid up on the Tyne, and to read the reports of the various steamship companies that, owing to absence of freights, the sailing of certain ships will have to be curtailed. The fact of the matter is that their present method of doing business is rapidly becoming obsolete. The foreigners who wish to buy goods from us will not always take it for granted that they are either the best or the kind wanted. The foreigner is essentially a man who at least wants to know what he will get for his money and to see what the goods are like. You cannot talk to him as you do to your own countrymen; maybe it is done through an interpreter. Make allowance for this. Think also of the mysterious ways of some foreign people, and you will begin to realize what has got to be done to secure their business.

One reason why orders pass us is because American and German firms have realized these points and have sent out men to study the conditions on the spot and to advise as to the best method of getting the business. This, especially, has been the case with the Germans, who have spent large sums of money in investigating the many little points which help them to successfully compete against all comers. They have in some cases gone into the most minute details, nothing being considered too trifling to inquire into. Knowing this, I fail to see how we can afford to neglect foreign trade when our competitors have found it worth while to study such details. In the last few years we have seen some very big strides in mechanical transport other than railways. The horse in many cases has disappeared, and a new state of affairs exists. With this new transport there has arisen a large and varied demand for machine tools, and as new districts abroad adopt new transport methods, this demand will require more attention, and that attention will have to be given by men who understand machine tools. We have seen the awakening of Japan and her rise in position to a world power. It is not unreasonable to assume that China will in time follow Japan, and it is time for us to ask ourselves whether we are going in for a share of the trade of that country, or whether we are going to sit down and do nothing but take what is sent to us. There is also India, capable of taking a deal more of our goods. The Eastern part of the world is being transformed and reshaped. Much of this reshaping is being done by engineers, and if we are going to partake of their benefits in the way of trade, we must send men out who can talk intelligently about the machines they require. We cannot wait for the agent to send home a requisition for a machine so lacking in information that it is impossible to offer anything. Rather must we furnish him with the information on the various points, so that his requisition may ask for something which we can supply.

THE COTTON INDUSTRY IN INDIA

By John Wallace

THE story of India's cotton industry differs, in many respects, from that of other countries, for, although the growth of cotton and its manufacture into cloth have been traced back to the remotest antiquity until it merged in the Indian mythology, the Indian worker never got beyond the simplest appliances for manufacture until the advent of machinery from abroad. The cotton worker, by caste, avoids the mills and prefers the old ways with their scanty remuneration. The mill hand is an agriculturist, who retains his connection with the land and only gives a portion of his life to the mill. The mill owner or agent is a merchant who has not yet realized the need of an industrial education. The mill machinery is all imported, and a large proportion of the technical managers continue to be brought from England. Bombay possesses the principal trade school in India, the Victoria Jubilee Technical Institute, where the art and science of textile work are taught, as well as those of mechanical and electrical engineering, but no millowner's son is to be found on the roll of students, and the Bombay Millowners' Association only represents seventy-three out of the 220 cotton mills in the country, the members being principally connected with local mills. As this association rarely presents a united front in matters of serious commercial importance, their common interests suffer a good deal, especially in relation to their employers, who, although they have no trade unions, are very difficult to manage, being very ignorant, superstitious, and undisciplined. The Indian mill coolie will strike, on a very small pretext, at one mill, knowing that he can get work at another. He can live without house or fire, and almost without clothing, and as his personal needs are of the simplest kind, he is by no means easy to coerce. Generally speaking, his agricultural life gives him a strong aversion for regular and punctual habits, and skulking has become a part of his nature. The situation of the Indian cotton industry is, at the present time, one that is full of interest, for, in spite of many drawbacks, due to defective organization and fluctuating markets, it displays a strong vitality and it generally compensates, through the commercial activity of its representatives, for any technical weakness in its administration.

The first cotton mill in India was known as the Bowreah mill; it was built in 1817, and was situated on the banks of the Hooghly, near Calcutta, but it disappeared without leaving any definite history or reliable details. According to official statements the first Indian cotton mill was started at Broach, in the Bombay Presidency in 1851, the year of the great exhibition held in London. The machines had wooden frames and were far inferior to those of to-day, but machines of the same character were still at work in a cotton mill at Tiflis in the Caucasus in 1884, producing coarse yarn that met the needs of local hand weavers. This mill, using the most antiquated cotton machinery in the world, had, at the same time, the most modern fuel (petroleum) to

raise steam. The first Bombay mill was built and owned by Mr. Cowasji Nanabhoy Davar, a Parsee merchant It was opened in 1854 under the title of the Bombay Cotton Spinning & Weaving Company, and contained about 20,000 mule spindles, with the necessary preparatory machinery, made by Messrs. Platt Bros., of Oldham. The mill worked successfully until 1887, when it was totally destroyed by fire. It was rebuilt and refurnished and is now known as the Motilal Mill. The progress of the mill industry since 1854 has been rapid, but complete statistics were not published until 1879-'80, when there were in India 63 mills with a total capital of 6,576 lakhs (a lakh is 100,000) of rupees. These mills had 1,610,600 spindles and 14,500 looms, and they gave employment to 51,000 persons.

At the end of 1906 there were in India, according to the report of the Director General of Commercial Intelligence, 217 cotton mills, containing 59,375 looms and 5,546,288 spindles; of this number 106 were exclusively spinning mills, ten exclusively weaving mills, and 101 mills where both operations were carried on. They employed a daily average of 136,406 men, 39,799 women, 20,856 young persons, and 14,095 children. During the year eleven new mills were started, with 95,548 spindles and 494 looms. The nominal capital of the mill was Rs. 172,689,894, including a sterling capital of £1,086,274, of which £850,521 was paid up; of the rupee capital, Rs. 128,870,256 was paid up. Twenty-six out of 39 mills worked by private proprietors had not reported the capital employed by them. It is estimated at Rs. 28,000,000. Seventy-one per cent. of the cotton mills are in the Bombay Presidency. In the native State and the French territory there are twenty mills with 4,084 looms and 316,268 spindles. Only 39 mills are owned otherwise than by joint stock companies.

Of the cotton yarn produced in India, nearly 75 per cent. is produced in the Bombay Presidency. Bengal produces 7, the United Provinces 5, Madras 5, and the Central Provinces 4 per cent.

The chief markets for Indian cotton, yarn and cloth have been China and Japan, but the active industrial instincts of the people of these countries could not be satisfied with the purchasing of goods they might themselves manufacture, so the Chinese have now begun to make their own yarn with the aid of English machinery, and Japan, with her 48 mills, is already engaged in keen competition with India for the possession of the China market. Japan, like England, does not grow her own cotton, but possessing a population with an extraordinary aptitude for handicraft, a climate superior for manufacturing purposes to that of India, and a government that is keenly interested in the furtherance of industrial schemes, she will eventually secure the bulk of the Chinese trade, unless certain changes can be brought about in the Indian methods of manufacture.

India possesses unlimited means for the production of cotton, and unlimited supplies of cheap labour, but agriculture is followed mostly on such a small scale as to preclude the use of economical methods of work in the field, and the commercial instinct being much stronger among natives of India than the industrial faculty, a large proportion of the profits of the agriculturist goes to the money lender and the land does not get the benefit of proper culture. Much has been done by the Government of India through its Public Works Department, in Sind and in the Junjab, by means of a well regulated and cheap water supply, to promote the interests of the agriculturist, and already Egyptian cotton is grown successfully in Sind, where the climate has much in common with that of Egypt. The crop is readily bought by Indian mill-

owners, several of whom are giving their attention to fine spinning. The working varies from 12 to 15 hours, and the value of the Indian mill coolie, when compared with the English mill hand in equal time, is 3, 4 or 5 to 1.

The average rates of pay per month are as follows: Head spinners (male), Rs. 25 to 35; pieces, Rs. 10 to 15; weavers, one loom, Rs. 10 to 15; two looms, Rs. 18 to 35; men, Rs. 7 to 15; boys, full time, Rs. 5 to 13; half-timers, Rs. 2½ to 4½; women, reeling and winding, Rs. 5 to 12.

The mill coolie takes frequent holidays, with or without leave, and, in addition, he will be absent from one to three months in a year to visit his village, and although agricultural work spoils his hands for mill work, his health is undoubtedly benefited, for the atmosphere of an Indian mill is under no official control. Occasional enquries into the subject of mill ventilation have been barren of practical legislation. The commission under the direction of Sir Hamilton Frere Smith which, in the winter of 1906, prepared a report on the condition of Indian factories made certain very practical recommendations regarding the improvement of the mill atmosphere, for the claims of ventilation are equally urgent on behalf of the operatives (who are known to be more alert and attentive to their work in a well-ventilated room), and on behalf of the processes of manufacture, for the cotton fibre is exceedingly sensitive to change of humidity in the surrounding air. So long as the Indian mills were confined to the production of the coarsest yarn, this influence was ignored, although its effect was observed during the rainy season, when the air imparted the best proportion of moisture to the cotton, but in proportion as the yarns were made finer, this peculiarity became more apparent, and recourse was had to the humidifier, an

OVERLOOKERS OR MUCCADAMS

apparatus suspended from overhead in which water at high pressure is discharged against an obstacle and broken up into floating mist that is absorbed by the air and by it imparted to the cotton. This apparatus does not renew the mill atmosphere, which consequently grows fouler as the day progresses. There are twice the number of operatives on the floor space that are found in English mills, with half the cubical air space, and as the working day is at least one third longer, the atmosphere of the mill grows very foul towards evening in the dry season when the windows are closed. Very few millowners have recognized that, if only for commercial reasons, the claims of the operatives are just as urgent as those of the machines and the cotton; they therefore provide appliances for moistening the air, while neglecting to renew it when foul. Although in the large centres of manufacture, like Ahmedabad and Bombay, there are to be found mill hands who have become detached from agricultural work, the greater proportion are still agriculturists who have had no serious training for mill labour. They are collected and engaged by a *muccadam* or contractor, who is also a supervisor in the mill. He levies a tax on every hand he engages, and has thus an interest in frequent changes. At all the mills there is a number of hangers-on who supplement the more regular hands, but who never work more than half time. This is the worst class of mill hands. The muccadam is rarely a first-class operative, and as an instructor he is almost worthless, so there exists no agency worth the name for the training of mill hands, and the coolies are quite content to remain at the class of work they started on, without showing any desire to go through the various departments. Working upwards from the blow room to the manager's office is quite unknown in India. The Indian mill hand might be a

A GROUP OF REELERS

much more serious adversary if he could bring the energy of the British operative to bear on his work. He has not the power of concentration of the piece worker of the colder climates, he is slovenly, and his love of noisy amusement when the fit is on him, on a holiday is due, overcomes every other consideration. Increase of income, instead of leading him to a better style of living, is often dissipated in amusement or vice, so that his absolute necessities remain as simple as before. The female mill hand is only employed for reeling; she works apart from the male hands and under a *naiken* or female overseer, who, like the *muccadam,* levies blackmail on her subordinates and may generally be recognized by the amount of jewelry she wears. The women are very independent and prompt to take offense, and if their physical appearance and dress on a holiday may be taken as an index of their condition, they do not appear to suffer from the effects of poverty or overwork. A short jacket with short sleeves is their only sewn garment, and the *sari* completes their dress. This is simply a long piece of coloured cloth which they wind about them very skillfully and which affords ample protection. Their children go naked up to the age of five or six; the furniture of their houses consists of a box or two, a rough wooden bed frame covered with coir yarn netting, and a few cooking pots of metal or earthenware.

MILL BUILDINGS

The Indian mill building was originally a copy of the English building, with a reduction of width for the sake of lighting, as artificial light was not used. The original type was afterwards copied with modifications, but with very little real designing. Spur gear transmission was abandoned, and rope and belt gear in general use by 1886, and in 1889 the steel-rolled beams came into use in floor frames, accompanied by the brick arch. About this time foundation stones for engines ceased to be imported from Europe and brick foundations took their place, but the old-fashioned chimney with a massive base, a square foundation and a fanciful top is still built in spite of the lesson which the cracks in the base continue to offer the millowner, and columns continue to be pivoted at the foot while they might be more securely fixed at less cost. In India mill managers frequently undertake the design of mill buildings. On page 694 is shown a mill in course of construction; its most striking feature is the bamboo scaffolding, which is tied up with coir yarn, without the use of a single nail or bolt. Scaffold accidents are nevertheless very rare in India, owing probably to the light weight of the coolie and of the load he carries. All material, even in the tallest buildings, is raised by coolie labour; this system is likely to continue because the *native* contractor has no mechanical training and has learned no trade. A knowledge of building rates, cost of labour and materials, and of the sources of supply, constitute his stock in trade. Technical details are left to the *maistry* or foreman, and the architect. Four sheets of drawings are generally found sufficient for a mill building, exclusive of those used for the setting of the engine and boilers, and plans are often altered during construction. The shed mill, which is usually the form preferred where land is cheap, offers the largest surface to the sun and is exposed to the greatest range of temperature within, being covered with dark red tiles which are never whitewashed. The saw roof of the shed is easily ventilated when the outer air is in suitable condition, but when a dry atmosphere is blown in off a roof heated to 120 degrees, the processes of manufacture suffer considerably. The windows are then closed and the air is moistened artificially. Armoured concrete has not yet reached the Indian mill building, although in

other structures it makes slow progress. The chief difficulty seems to be in the unreliability of the workmen and foremen, who are quite unused to work of the best class and who will not honestly carry out any work as specified. The local insurance offices now insist on an adequate provision of appliances against fire risks, and the automatic sprinkler is in general use along with steam fire pumps and hose, but various recent and destructive fires have betrayed a lack of readiness and discipline that is still too characteristic of the country. The Indian night watchman is not yet cured of his habits of sleeping or smoking while on duty even under the stimulus of the tell-tale clock, and the Indian manager too readily forgets the importance of frequent fire drill.

About 100 out of 224 cotton mills are fitted with electric lights in order to extend the period of working beyond that of daylight, but owing to the excessive hours worked in some of these, it is probable that, by legislative restrictions regarding the hours of children and young persons, the mill day will be reduced to a daylight limit averaging 12 hours and 5 minutes or to a uniform 12 hours. In the former case the demand for artificial lights will cease.

A COTTON MILL UNDER CONSTRUCTION

The largest cotton mill in India is the Jacob Sassoon in Bombay, a handsome five-story structure built in 1893 for Messrs. E. D. Sassoon & Co.

It contains 93,875 spindles and 1,810 looms and finds employment for 4,000 operatives. The horizontal compound driving engines are of 3,350 horse-power, which is transmitted by rope gearing to the line shafts.

The engines used in Indian mills are of the best class owing to the average high price of fuel. Horizontal compound condensing engines are the favourite type, but there are

also some fine types of vertical engines, all built by British makers. The inspection of boilers is so rigid that explosions are practically unknown. Feed water is frequently bad and the old custom of purifying the water in the boiler is still general, causing much damage to flues. The Lancashire boiler is generally used in factories, but during the past fifteen years the water-tube boiler has made a good deal of progress, especially where high pressures are desired or where transport to the factory is difficult. The chain-grate stoker has done a good deal to popularize this class of boiler, as it is one of the very few stokers that will burn Indian coal without smoke and with a moderate draught. The Diesel oil engine is already in use in several cotton mills and is likely to find extended employment where the distribution of cheap oil is better organized. Water power is only used by two cotton mills in India belonging to the Gokak Water Power Manufacturing Company at the Gokak Falls in the Bombay Presidency, but an important scheme is in hand by which the monsoon rains will be stored in an upland valley of the Ghats fifty miles from Bombay to drive turbines with a fall of 1,700 feet, and their power will be converted to electric current and transmitted to Bombay for the use of the mills and other consumers of power. The cheapness of electric current so produced is likely to give it the preference among the various industries of the city. It is also probable that at or near the outfall of the turbines paper making, bleaching or dyeing will find a suitable location on account of the steady flow of water which will be available throughout the year. All water courses are dry in the neighbourhood of Bombay for six months annually.

A TYPICAL SHED MILL

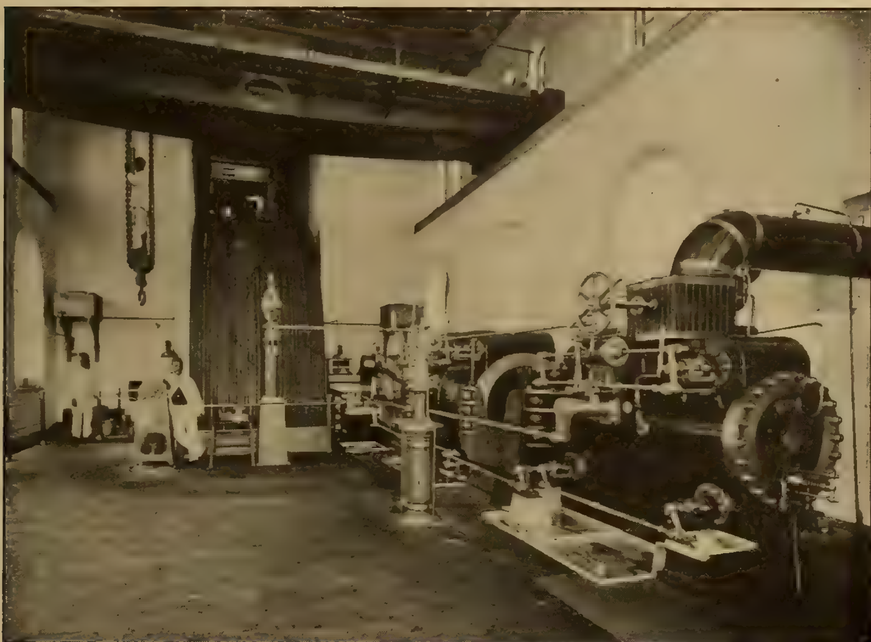
GINNING

The ginning of cotton, although only a seasonal industry lasting about four months, is a very popular investment among native capitalists. There are approximately 1,401 ginning factories in India containing each an average of 25 gins and driven for the greater part by steam engines. They are principally under native management and the deprecia-

tion of the machines is heavy, owing to careless supervision. The saw gin of American manufacture was the first introduced, but owing to the adhesion of the fibre to the seed of Indian cotton the saw proved destructive. The Macarthy gin is now in general use in factories, many parts of it are now made in India, and it is probable that complete gins will ere long be made. The improvement of the drawing roller has been the subject of many local patents, one of the most recent being the substituting of disks of split bamboo matting for those of leather. About 700 of these are required for one roller, and when thoroughly compressed they offer a surface that is said to be efficient, presenting a large proportion of end grain in all directions. The oil engine is already used to a small extent in ginneries and it is likely, in time, to supersede the steam engine entirely, as it dispenses with the attentions of the boiler inspector. In spite of the number of steam ginneries considerable quantities of the best cotton are still ginned by the *churka*, a very primitive and simple machine of wood, containing two small rollers of such size that when the seed cotton is presented to them the fiber is seized while the seed is rejected. The rate of work is very slow, amounting to only 12 or 14 pounds per churka per day, but less fiber is broken by this than by any other process, labour costs two annas per day or less, no building is required, and the churka may be had for 3 to 5 rupees. If a good designer would take this machine in hand the efficiency of the worker might easily be increased six times, causing a revival of the churka like that of the handloom, but judging from the very rough attempts at improvement that are to be seen at exhibitions, the right kind of inventor is not drawn to it. He probably thinks that if the invention were too simple a patent would offer no real protection, while if it contained any but the most ordinary details a very well organized factory would be required to produce it cheaply enough. The improvement of the churka might be worth the attention of the Salvation Army, whose admirably installed steam factory in

THE JACOB SASSOON MILL, BOMBAY. THIS MILL WHEN FULL WILL CONTAIN ABOUT 100,000 SPINDLES AND 2,000 LOOMS

Bombay is now producing cheap hand looms of excellent design with standardized details. The success of the ginning factory in India has resulted in the establishment of many bogus ginneries fitted with second-hand machines and owned by wealthy speculators who will work at a loss until the other ginners agree to pay blackmail. Then the bogus factory is closed. At Dhulia, in Khandesh, there are nearly twice the number of ginneries required for the actual work of the district and nearly half of them remain closed in ordinary seasons.



A TYPICAL MILL ENGINE

PRESSING

The reputation of the Indian cotton bale has spread to every part of the commercial world, and this distinction is of no recent origin, for, from the beginning of the cotton trade, the cost of cotton freight over long distances compelled the pressers to do their best work. Up to the time of the American War in 1863 packing was effected by means of wooden screws of large size cut by hammer and chisel from specially selected logs of hard wood; the nut was made in halves and bolted together. Working at the rate of only four bales an hour the air had ample time to escape from the cotton, ensuring a satisfactory density of bale, which was tied up with ropes. Soon after this the hydraulic press appeared, which was soon followed by the finisher, giving by a second process an additional squeeze until at the present time cotton bales average 400 pounds in weight, with a density of 34.8 pounds per cubic foot and a volume of 11.5 feet. They are tied with continuous hoops passing 12 to 14 times round the bale, and fastened by inserting the end into the preceding loop. The constant cry for increasing density led to frequent breakdowns of the presses and corresponding improvements. The cast-iron hydraulic cylinder was exchanged for steel, and steel super-

seded wrought iron in the pipes. Levers disappeared in favour of direct pressure, until a limit was formed in the matting of the cotton fiber, which then suffered in the subsequent opening process at the mills. The state of the atmosphere at the time of pressing has a considerable influence on the rate of work, as cotton loses much of its springiness in damp weather. A press that can turn out 32 bales per hour with water at 1 ton per square inch requires 1¾ tons in very dry weather when it can only produce 28 bales. Breakdowns generally occur at such times. To keep up the maximum rate of work the cotton would have to be conditioned by means already in use in the cotton mills. A hydraulic cotton-bailing press is a costly machine whose value, installed, may amount to Rs. 37,000; and as its working season corresponds with that of the gin, it must be idle the greater part of the year. An attempt is now being made to introduce a new horizontal baling press (somewhat on the principle of the Dederick hay press) for baling cotton as it issues from the gin. This new machine, which costs a fraction of the price of the hydraulic press, is driven by a belt, and is intended to render the ginneries independent of the latter and to save the time that is now lost in the packing, transport and waiting that is at present inevitable when the two processes are at some distance apart.

BUNDLING AND BALING PRESSES—YARN PACKING ROOM

The cotton industry in India now includes spinning, plain and fancy weaving, dyeing, calendering and finishing, mercerizing, bleaching, hosiery, sewing thread cords and twines and many varieties of coloured and fancy cloths for outer clothing. Sail-cloth is also largely made, much of it being hand woven. A company has recently been formed for calico printing by machinery, but the development of hand printing, an old industry in the country, has been much neglected in spite of the establishment of schools of art in various places. Hand printing after the system employed in Japan is more

adapted to the taste and resources of the people than machine printing, and a large market exists in Africa for this class of work, not to speak of the market in Europe for high-class hand prints.

The cultivation of cotton on scientific principles progresses slowly in India on account of the indifference of large land holders and the poverty and ignorance of the small farmers. The Government has already done much for the improvement of agriculture by means of model farms and the publications that issue from the Agricultural Research Institute at Pusa. But the cultivators are illiterate and they speak many different languages and dialects, so that a knowledge of English is necessary for any serious course of study in agriculture. But the great bar to the progress of the cotton industry in India is to be found among the operative class who, instead of belonging for life to one industry, as in other countries, divide their time between the cotton mill and field labour or other work. The operative does not care to know anything thoroughly, and his migratory habits have only recently been disclosed in the report just issued of the Indian Factory Labour Commission 1908, the most complete enquiry hitherto made into the condition of factory labour in India.

From this report it appears that about 18 months is the maximum period that a mill hand will pass, continuously, in one mill, and that men over 40 years of age do not continue at mill labour. A remarkable feature of this report is that after a careful examination of many hundreds of operatives in various parts of India, the medical members of the commission can hold diametrically opposite opinions regarding the influence of mill labour on the physique of the operatives. It was clearly established that very long hours resulted in smaller and worse production than a day of from 10 to 12 hours. It was also agreed that the state of the mill atmosphere was foul enough to demand legislative interference, although this latter opinion was, unfortunately, not supported by analyses of the air in any mill. An Indian cotton mill is a little larger per spindle than an English factory, but the double number of operatives at work at any time fouls the air at an increasing rate which is augmented by the higher temperature of a tropical country. This higher temperature increases in its turn the amount of excreta from the skin. If the members of the commission could have passed one whole day in any mill they would have gained an experience that might have resulted in a very positive opinion on the subject of mill ventilation. Employers complain of the scarcity of steady mill hands at all times; it would therefore seem that the great increase of their earnings, beyond those of field labour, has not attached them seriously to the mill with its humid, foul and relaxing atmosphere. Regularity of attendance and close attention to work are impossible. India fortunately possesses at least one large cotton mill which, although ventilated to an extent unknown elsewhere, has been singularly successful. The Empress Mills, Nagpur, belonging to Messrs. Tata & Sons, has the air of the cardroom renewed eleven times per hour, and that of the spinning room fourteen times, and although the dryness of the climate renders it very bad for cotton manufacture, no difficulty is experienced in introducing the necessary amount of moisture, with its accompanying reduction of temperature.

The difference between the impurity of the air of such a factory and of one in which the air is moistened without any but accidental renewal may be left to the reader's imagination, for in very dry weather the windows are purposely closed to exclude the wind.

As education is not compulsory in British India, the bulk of the mill hands are illiterate. Millowners have

been advised to establish schools for the children of their hands and some have actually done so, without much reflection on the meaning of the term education. The results hitherto accomplished have not been worth recording except as an illustration of how teaching should not be carried out. Reading, writing and counting, taught in an ancient style by very incompetent men, do not develop the intelligence of the children, nor do they cultivate the wholesome habits of observation and curiosity, and of rational thinking, that are to be seen in all good workers of other countries.

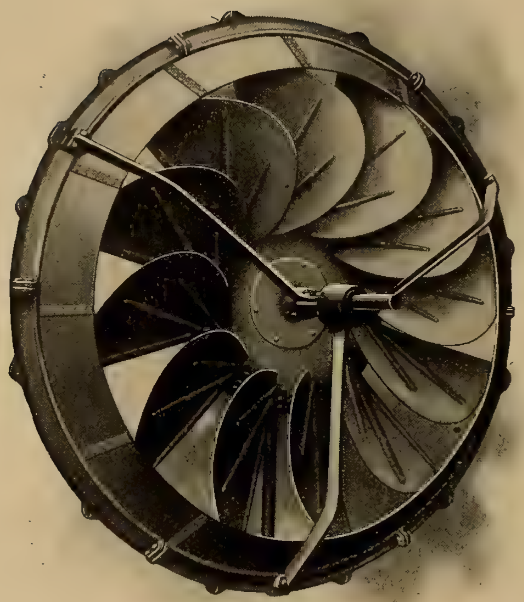
No one who has any industrial experience of Indians will deny that many become excellent workmen, but, like the Europeans, they need training, a process they are inclined to shirk. The progress of the cotton industry in India seems now to depend on three principal things: Improved cultivation of the fiber from selected seed; appropriate training of the operatives, and the adoption of good methods of ventilation which are already in successful operation in the country.

COOLING TOWERS

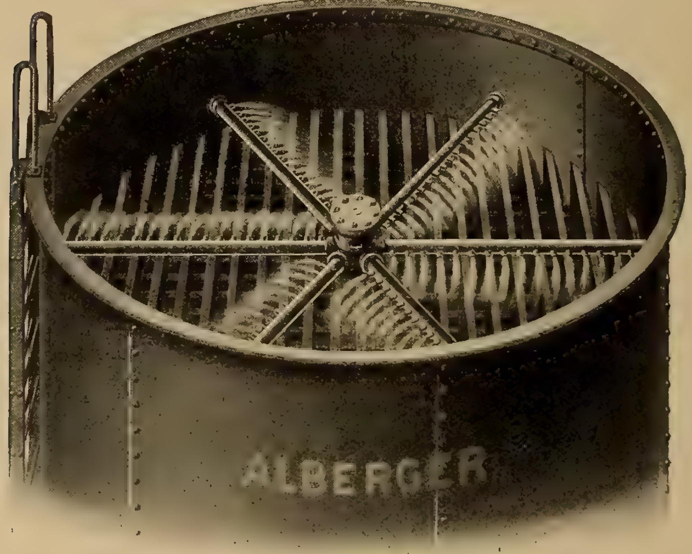
By Samuel K. Pattson

OF all the recent developments in the construction and operation of power plants, the cooling tower has advanced with probably greater rapidity than any other, and they have, as an engineering development, passed the experimental stage and come to stay. This development has been chiefly along the lines of economy in operation, while considerably less has been done with the constructive details of the plant itself. The great rapidity of their progress is due to the filling of a long-felt want, and because it involves no new or radical engineering problem. Their application is greatly increasing, and standardization of form is rapidly approaching. With the steady increase in size of power plants and power plant units, and the resulting demand for economy of operation, has arisen the necessity for limiting the location of such plants to localities where a large water supply is available, as the quantity of water consumed by a modern power plant is remarkable. Where such plants are so situated that they must purchase their water supply, the bill is no inconsiderable item of expense, and the development of the cooling tower offers a simple and inexpensive means of either eliminating the locality limitation, or of reducing the water bill by repeated utilization of the same water. Notwithstanding the many advantages, and partly because its development has been so rapid, and of its novelty to the majority of engineers, cooling tower engineering is to-day somewhat chaotic, and a practical knowledge of the best conditions for operation, construction and installation under given external conditions is possessed by few engineers.

In a very great variety of applications, cooling towers serve simply for the purpose of cooling water from a high temperature to one sufficiently low to permit of its being used again for the same initial purpose. The use of steam condensers in large power plants is becoming more and more nearly universal, and as a means of further conserving and utilizing water supply, the cooling tower in connection with the condenser is fully as valuable. In this application it is used to cool the condenser water after it has absorbed the steam, and the addition of water condensed from the steam more than compensates for the loss by evaporation during the cooling process. This latter condition, of course, does not exist where the condenser is of the surface type, as in this type the condensing water does not mix with the condensed water. Cold water is also used in refrigeration for operation of the condenser in the compression type and both the condenser and absorber in the absorption type, and as a cooling tower is efficient in practically any size, its range of application is great. In gas engine operation, water is a requisite to cool the cylinder, and as it requires from 8 to 10 gallons per horsepower hour, the quantity of water used to cool a large engine from the city mains would materially increase the cost of operation. Further, some waters are unsuited for these purposes on account of contained salts which form a deposit in the water



VIEW OF FAN, SHOWING ARRANGEMENT OF BLADES. ALBERGER CONDENSER CO., NEW YORK



VIEW OF TOP OF TOWER, SHOWING DISTRIBUTOR. ALBERGER CONDENSER CO., NEW YORK

spaces and impair the efficiency of the cooling. The cooling tower will, in either case, eliminate a large percentage, if not all, of the difficulty.

Therefore, while the prime object is the same, the cooling of water, cooling towers have been installed for two entirely different reasons; first, the difficulty of obtaining large supplies of water, or its obtainance at large cost, and, second, the availability of water, but undesirable on account of its unfitness, through impurities, for special purposes. The consideration regarding the unsuitability of water, the presence of salts, sediment and other impurities that render it undesirable for boiler or gas-engine cooling work make the installation of large and expensive filters necessary. These are often inefficient and require great care, and the maintenance cost is also a factor. It is often the case, too, that chemicals must be used to soften the water.

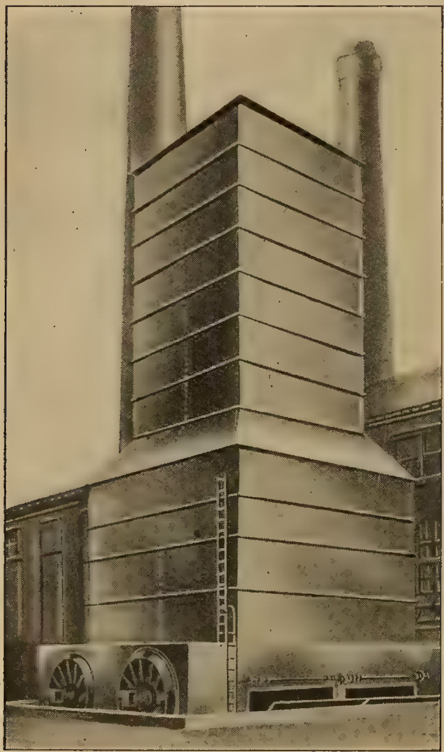
It can, therefore, be readily seen that the use of a cooling tower not

ALBERGER COOLING TOWERS SUPPLYING THE WATER FOR THE CONDENSER OF A 2,000-K. W. STEAM TURBINE. ALBERGER CONDENSER CO.

cost factor may arise either from a lack of available water, or the necessity of purchasing it at a large figure, either from an adjacent plant or from the city, or from the great expenditure involved in installing suitable pumping equipment and its maintenance. As this latter condition is not often a determining factor, cooling towers should be installed for this reason alone in extreme cases only. The other conditions in the majority of cases are sufficiently important to render the installation advisable, if not absolutely necessary. In the second

only reduces the consumption of high-cost water, but by conserving and cooling the water in use, so that it can be used over and over again, further reduces the operating expense. Wherever cold water in quantities is needed, and whenever this water becomes unserviceable through heating, a cooling tower becomes necessary for the best economic operation, and eliminates the condition which has, until recently, been imposed on large power plants, namely, that of being situated in the immediate vicinity of a suitable water supply available at small cost.

The principle back of a cooling tower is based simply upon the absorbing power of the air for water-vapour and the consequent cooling of the water from which this vapour is obtained. The conception that they cool the water by conduction is a fallacy, and has led to many wrong theories and objectionable construc-



COOLING TOWER AT THE WORKS OF THE CELLULOID COMPANY, NEWARK, N. J. C. H. WHEELER MFG. CO.

tive details. Development has therefore been along the line of providing a means whereby water at a high temperature is, in contact with air, permitted to flow over, through, or around various devices for retarding its rapid progress and prolonging its intimate contact with the air, and thus cooling it, by the absorption of water-vapour, to a lower temperature suitable for use.

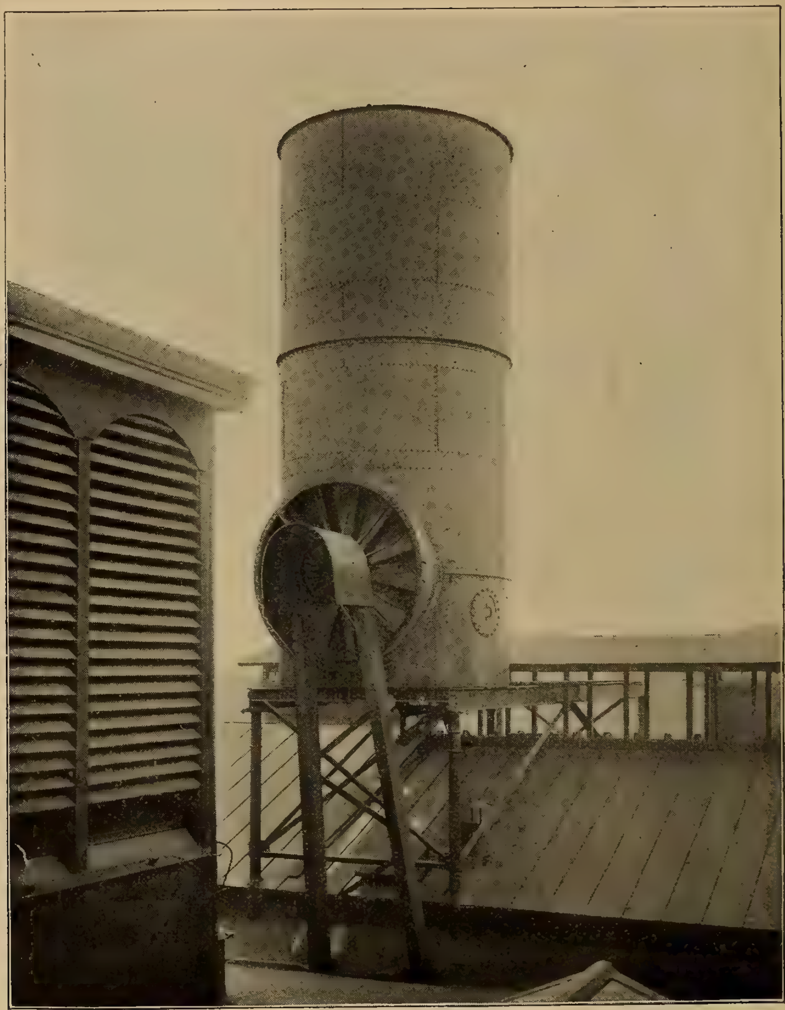
Water-vapour fills the entire space surrounding the earth, and the science of this department is known as hygrometry. The subject of moisture in the air and hygrometry in general is in rather an experimental stage from the viewpoint of practical engineering and little data is available to the ordinary engineer, while even the instruments for its measurement are unfamiliar and often unavailable for use. Air absorbs heat in two ways: by being heated by conduction from direct contact with the water, or by the evaporation of water-vapour into the air. The first is practically negligible, as the specific heat of air per unit volume is small, and it is also a poor conductor and heats slowly. The evaporation of a portion of the water into the form of vapour, which is carried off by the air, is very efficient, although the quantity of vapour which may be absorbed by the air is variable and dependent upon the temperature of the air and degree of saturation. Air possesses the property, dependent upon its temperature, of carrying in it a certain proportion of water in the form of vapour, which behaves as any other vapour and becomes saturated on contact with liquid of its own material. Thus, in the vicinity of large bodies of water, the water-vapour is saturated, while at greater distances it is in an unsaturated condition and readily becomes saturated when brought in contact with a body of water. The carrying power of air for water-vapour is much greater at a high temperature than at a low one, and we have the anomalous condition of water being cooled off more quickly by hot, dry air than by cold, dry air, for while the small quantity of water-vapour taken from the water by the cold, dry air would, in proportion, cool the water enormously, due to the liquid becoming vapour and absorbing its own heat of evaporization from the surrounding water, the hot, dry air, having a larger capacity for water-vapour, cools the water much more rapidly. Therefore loss in efficiency, due to the temperature

of the air, is more than compensated for by this increased absorptive power for water-vapour. As air can carry only a relatively small quantity of water-vapour, large quantities of air must be used, and until recently a forced blast to drive the air over the water was considered the most efficient process. This is now considered objectionable, however, as the air very rapidly becomes saturated before it has passed over any considerable portion of the water, and the remainder of its passage is practically useless as far as cooling effect is concerned.

Cooling towers, then, depend absolutely, for their operation, upon the extent of vaporization produced in the water during its passage through the tower, and the loss by evaporation in a single passage of the water through the tower varies from 5 to 10 per cent. It is, therefore, obvious that the cooling tower does not entirely eliminate the demand

WHEELER-PRATT WATER-COOLING TOWER, FORCED-DRAFT DESIGN.
C. H. WHEELER MFG. CO.

for water in plants in which they are operated; they merely diminish the amount required. Where plants demand a large amount of water, and are located in large cities or elsewhere, without a supply imme-

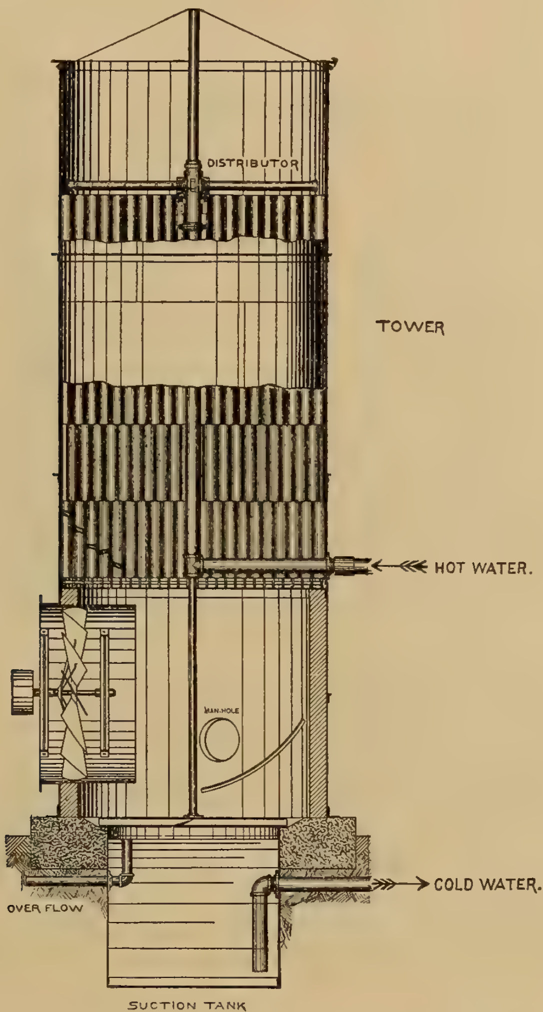


WORTHINGTON SELF-COOLING CONDENSER ON ROOF OF ENGINE HOUSE

diately available at a low cost, cooling towers are undoubtedly very economical, absolutely cutting down the consumption of water to only 5 or 10 per cent. of its former amount, and in most cases the cost of the tower and maintenance compare very favourably with the reduction in the water bill. It is not uncommon for the saving to be at least 50 per cent. in many large plants where towers have been installed, and when the operation is in the charge of a competent engineer this figure may often be exceeded.

Generally speaking, there have been two kinds of cooling towers developed as a result of experiment and use, and these are called, respectively, the closed tower and the open or atmospheric tower types. These two types are in many respects es-

sentially the same, in that both consist of a square, rectangular, or round tower rising into the air for from 20 to 60 feet, and having water pipes for conveying the hot water to the top, with various sprinkling devices at that point, to spray or distribute the water. The closed type differs, in theory at least, from the open type, only in the fact that the sides are closed and contact of the water with the air is accomplished by means of a power fan located at the base. On the other hand, the atmospheric type has the walls of the tower open, and admits air from all sides into immediate contact with the water. There are many variations of these two types on the market, the differences appearing chiefly in the cost of erection and details of construction. In this latter respect, however, cooling towers are, broadly speaking, merely in their inception, for no two makers have identical plans or data for use in

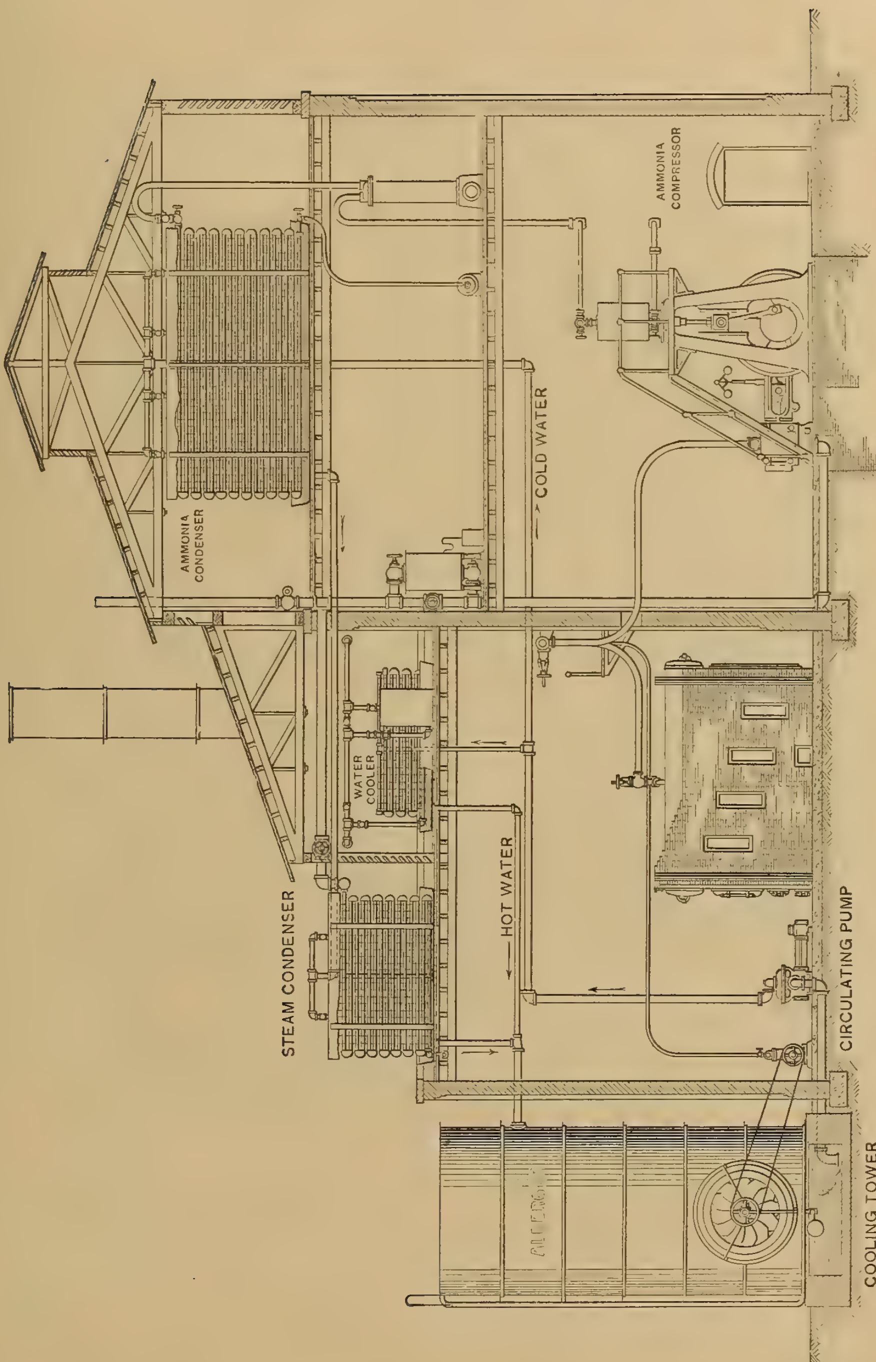


SECTIONAL VIEW OF WORTHINGTON COOLING TOWER

estimating. Thus, cooling towers of the same estimated capacity are of varying heights and dimensions, apparently chosen at the option of the contractor. In the open type, some are covered with a lattice or screen, to prevent loss by wind-blown spray, while others are utterly devoid of this feature. In some constructions of this type are installed vanes or wind shields to accumulate and direct the air for passage over the exposed water. These may be placed on all sides, or only on the sides from which come the prevailing winds. So that, while cooling towers have, notwithstanding the wide variance of design, attained to a remarkable degree of efficiency, there is great room for improvement, and standardization.

In addition, an entirely satisfactory and suitable constructive material, considering all the factors of first cost, desirability and installation, has not yet been found, and the materials heretofore used have varied almost as widely as design. Wood and iron, a combination of the two, and even reinforced concrete, have been utilized in various designs, and when it is considered that the deteriorating effect due to the intimate contact of water and air in this con-

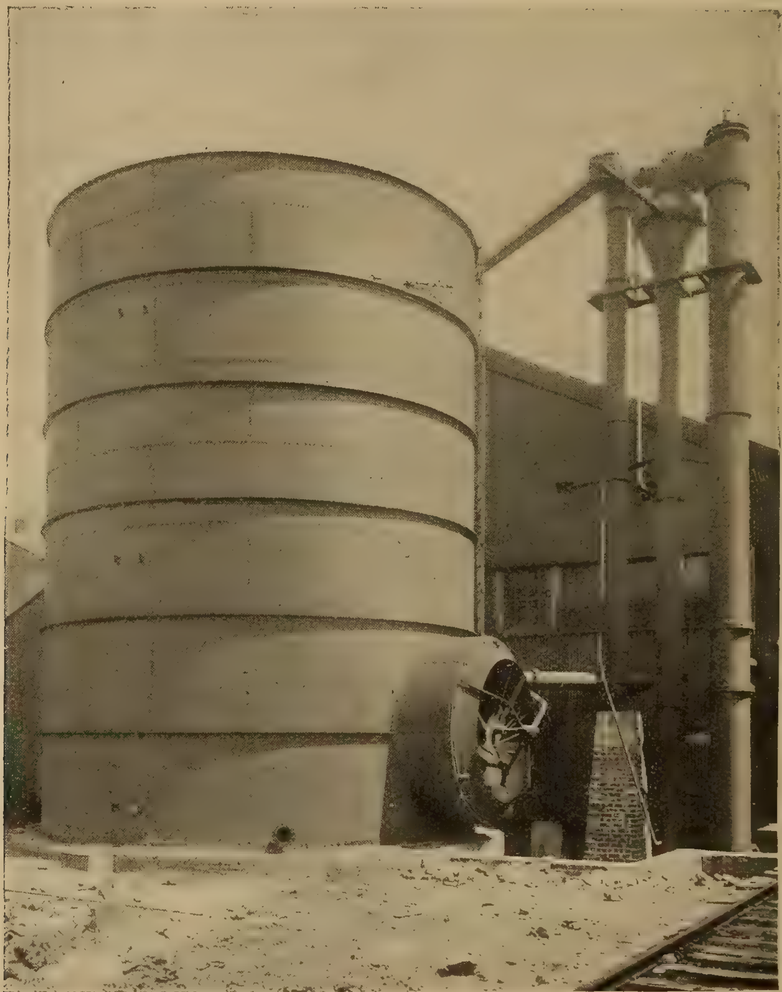
WHEELER-PRATT WATER-COOLING TOWER, NATURAL-DRAFT ROOF TYPE.
C. H. WHEELER MFG. CO.



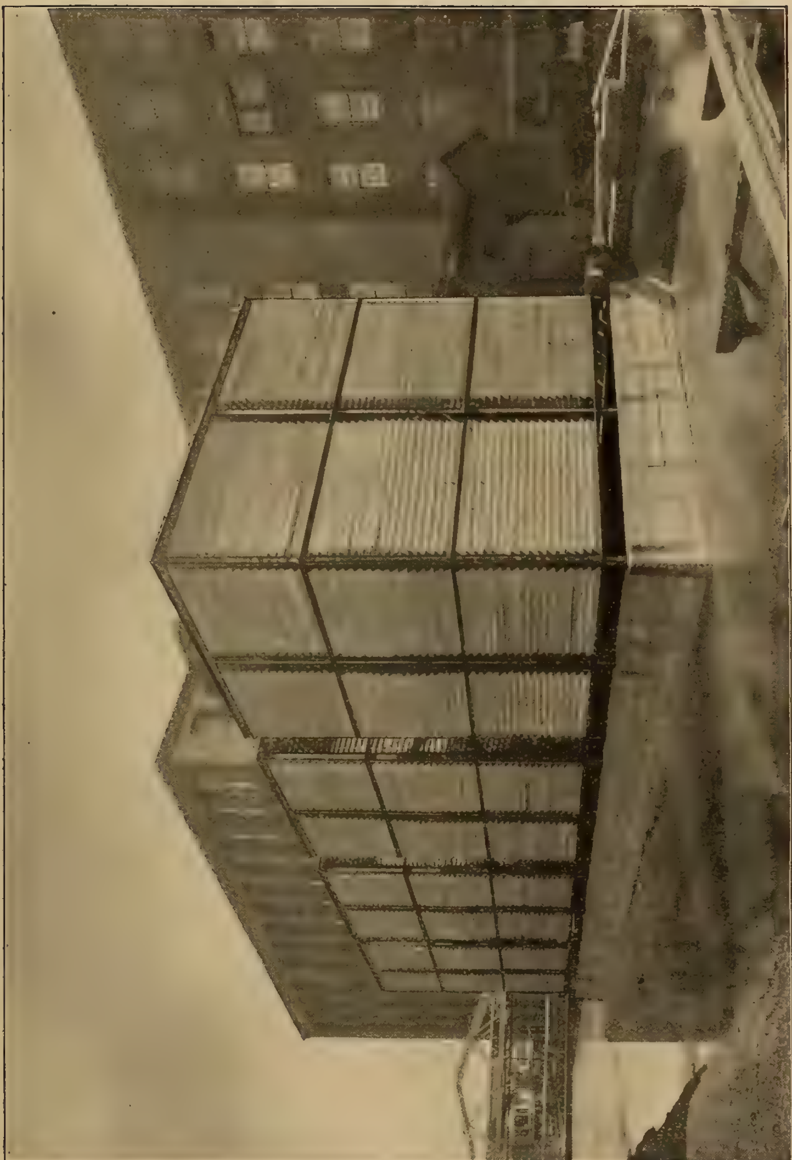
ALBERGER COOLING TOWER AS USED WITH AMMONIA AND STEAM CONDENSERS IN AN ICE-MANUFACTURING PLANT. ALBERGER CONDENSER CO.

dition is very great, the difficulties in the way may be appreciated.

The large surface for exposure to the air is obtained in many ways; for instance, the Burhorn and Hart types utilize a series of large shallow pans, one above the other, and slightly tilted, the alternate pans being parallel with each other, and the water either overflowing in these pans or escaping through a series of holes made in the bottom of each pan at the lowest edge, falls by gravitation over the bottom of each pan in succession. Slabs of wood or slate similarly arranged, and for the same purpose, are used in other designs. In another type the water is allowed to run into a series of horizontal parallel V-shaped pans, which overflow when full, and the overflow is caught by a similar series of pans placed below the first, and so on through the entire height of the tower. Or the V-shaped pans may have apertures in the apex of the V, thereby allowing the water to escape to the lower levels. In



WORTHINGTON COOLING TOWER. CAPACITY, 2,000 HORSE-POWER



WHEELER-PRATT WATER-COOLING TOWERS, NATURAL-DRAFT TYPE. C. H. WHEELER MFG. CO.

the closed type, the Alberger tower has a series of horizontal parallel cypress planks equidistant from each other and resting on their narrow surface, superimposed at right angles upon another similar series, and so on for a number of layers, while the Worthington tower consists of short, vertical lengths of interlocking galvanized pipe, arranged in layers to permit of dividing the water into innumerable channels as it descends.

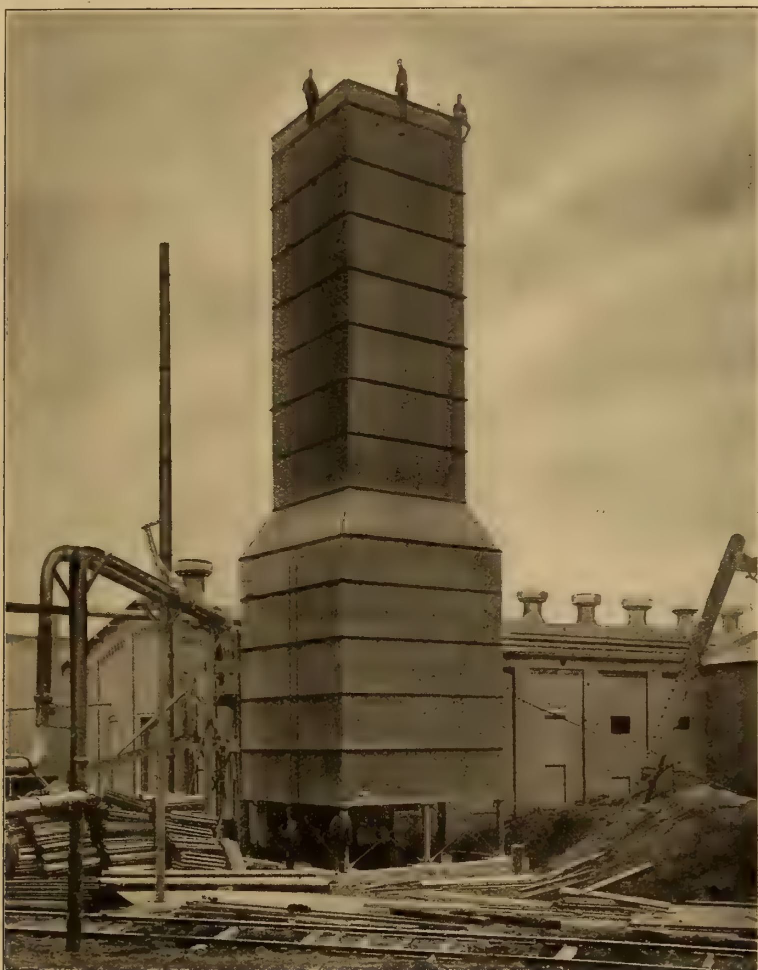
In comparing the relative efficiency of the two types, the closed type was formerly considered to be superior, due to the fact that the fan was supposed to force much more air over the surface of the water than in the atmospheric type. As has been explained, however, it is found that the air rapidly becomes saturated and is ineffective during the latter part of its passage over the water. In this type, therefore, a given quantity of air, forced into the lower part of the tower, must, in ascending, come in contact with and move parallel to constantly falling streams of water, and after absorbing from the water which it first reaches its full quota of water-vapour, it is practically useless during the remainder of its progress; whereas in the open type the descending water is brought into contact with an air current, moving nearly always at a right angle to it, and never parallel, so that the water passes through successive layers of air that will take the water-vapour from it. It is therefore recognized to-day, from an operative point of view, that the atmospheric type is superior in cooling efficiency. The fact that in the closed type the operation of the fan requires power, and that this latter must be considered as a cost factor in the operation of the plant, has also enabled the open tower to successfully compete with its rivals.

The first cost of a cooling tower is an exceedingly variable quantity. Construction consisting simply of a pile of wood in a frame, the parts overlapping so as to present a maximum path for the flow of the water and open to the air, is extremely simple in construction, low in cost, and fairly efficient. From this simple design on up through the various types of iron or wood, or both, with varying devices for obtaining a large surface of water, there are widely varying degrees of cost, until in the large steel tank, with large capacity rotary blower installed for forcing the air through the tower, a considerably different question is reached and the cost is relatively greater. The closed type of tower, therefore, may triple or quadruple the first cost of an open type tower, so that, its efficiency being less, it would cease to be an active competitor if it were not for other conditions. These conditions center about cost of maintenance, reliability, and various considerations of a more or less urgent character, which in general hold against the open or atmospheric type.

The maintenance is also a feature for consideration, and there is no doubt that the closed type is much superior in constructive details and general development. While, with its sides closed, it is not nearly as subject to weather conditions, and the deteriorating effects resultant from these, the fact that its sides are closed renders the difficulty of cleaning and repairing a decided disadvantage, as compared with the open type, in which the parts are readily accessible. The closed type is, however, from the nature of the design, a much stronger and more permanent tower.

So far as reliability is concerned, a cooling tower is subject only to weather conditions and accidents to the pumping or blowing machinery. A cooling tower of the open or atmospheric type has a certain definite capacity for cooling water under any given set of weather conditions, which natural capacity cannot be exceeded, and its performance is thus dependent, to a greater extent than

the closed type, upon the hygrometric conditions existing in the atmosphere, and its temperature at different times. Thus the quantity of air coming into contact with the water is dependent upon the wind, hygrometric conditions of the atmosphere can be offset by measures which reduce them to a minimum. Under such conditions the speeding up of the fans, with a resultant increase in air supply, will often com-



WHEELER-PRATT WATER-COOLING TOWER, FLUE TYPE. C. H. WHEELER MFG. CO., PHILADELPHIA

and its efficiency varies with the humidity or quantity of water-vapour present in the air. Therefore, under certain conditions, the closed tower may become more efficient because its adaptability is greater; it is not dependent upon the wind for a fresh supply of air, and bad pensate for a high hygrometric state, and thus render the operation of the tower more uniform. A further objection to the open type, which often assumes great importance, and is due to conditions existing in large cities, is worthy of serious consideration. This is the

fact that an open tower of the ordinary type loses and wastes a large amount of water when a high wind is blowing by the wind carrying it through the sides of the tower in a fine spray. This is often sufficient to thoroughly wet the surrounding properties, and in some cases has resulted in tedious and troublesome law-suits; in any case it invariably hastens the deteriorating effects of water and moisture on the surrounding objects. This difficulty has been met in some forms of construction and removed by providing on the side or sides of the tower opposite to the direction of the wind a system of spray shields, which return the wind-blown spray to the tower.

It is therefore to be seen that each type represents a different field, with its own advantages and disadvantages. The closed type is efficient and reliable, not as efficient at its best as the open one, but more reliable. It costs more to install, but complicated conditions are not apt to often arise in its maintenance, other than those of a mechanical nature. On the other hand, the open type requires no machinery in its operation, and it is the most efficient under ordinary circumstances. The result has therefore been that large and efficient plants, with considerable capital behind them, have almost invariably installed the enclosed type. Smaller units, in which cost is an important consideration, have installed the open type. Large power stations in cities, operating trolley and lighting systems, very generally have cooling towers of the closed type, while small refrigeration plants almost invariably adopt the open one. Plants midway in this classification are variable in their choice, dependent upon variable local conditions.

Both types are in active and efficient operation to-day; their use and application are rapidly becoming more general; their principles are being more fully understood, and their design is tending toward standardization. It is eminently desirable that standard types be developed in this line, and experiments made to determine the most suitable structural material, as this branch of engineering, which offers great advantages from both an economic and efficiency standpoint, should be developed to its maximum possibilities.

DRYERS AND DRYING

By W. B. Ruggles

THE subject of drying is such a broad one that it cannot be disposed of in a single article, and hence the drying of materials such as lumber, brick, etc., which require a heated chamber or tunnel, will be omitted, and only such materials as may be dried in machines by continuous operation will be considered.

It has been found impracticable to dry all kinds of material in one type or dryer, due to the different physical and chemical properties of such materials, and it is therefore necessary to arrange materials in general groups and design different machines for each group. In certain cases, however, a material placed in one group may best be dried in a machine designed for another group.

Group "A," for materials which may be heated to a high temperature and are not injured by being in contact with products of combustion. These include cement rock, binder rock, sand, gravel, granulated slag, clay, marl, chalk, ore, bauxite, carborundum, graphite, asbestos, phosphate rock, slacked lime, fullers earth, etc.

The most simple machine for drying these materials is a single revolving shell with lifting flights on the inside, the shell resting on bearing wheels and having a furnace at one end and a stack or fan at the other. The advantage of this style of machine is its low cost of installation and the small number of parts. The disadvantages are the great cost of repairs and the excessive fuel consumption. If the material is fed from the stack and towards the furnace end, the shell near the furnace gets red-hot, causing excessive radiation and frequent repairs. Should the feed be reversed, the exhaust temperature must be kept above 212 degrees or recondensation will take place, wetting the material. In either case radiation from the shell is great, and the stack gases are of high temperature.

To overcome the poor efficiency of a single shell dryer, many have resorted to the method of supporting the shell at the ends, erecting brickwork around the shell and having the fire pass under the shell and back through it. Although this method is more economical in the use of fuel, the initial cost of installation is much more. In operation, there is considerable radiation through the brick walls. It takes about an hour to heat the dryer in starting, and in case repairs are needed a long time is required to cool it down. The worst feature about this type, however, is that the shell is heated and cooled alternately on different sides as it revolves, which causes unequal expansion, with the resultant buckled plates, sheared rivets, open seams and constant repairs.

Another group, which we will call "B," are such materials as will not be injured by the products of combustion, but cannot be raised to a high temperature on account of driving off water of crystalization, breaking up chemical combinations, or on account of danger from ignition. Included in these are gypsum, fluor spar, iron pyrites, coal, coke, lignite, sawdust, leather scraps, cork chips, tobacco stems, fish scrap, tankage, peat, etc.

Some of these materials may be

dried in a single shell dryer and some in a bricked-in machine, but none of them in a satisfactory way, on account of the difficulty of regulating the temperature, and, in some cases, the actual danger of explosion of dust.

A third group ("C") of materials are those which are not injured by a high temperature, but which cannot be allowed to come into contact with products of combustion. These are kaolin, ochre and other pigments; fullers earth, which is to be used to filter vegetables or animal oils; whiting and similar earthy materials, a large proportion of which would be lost as dust in direct heat drying.

These may be dried by passing through a single shell dryer encased in brickwork and allowing heat to come into contact with the shell only; but this is a very uneconomical machine to operate, due to the very high temperature of the escaping gases.

A fourth group ("D") are those organic materials which are used for food either by man or the lower animals, such as grain which has been wet, cotton seed, starch feed, corn germs, brewers' grains and breakfast foods which must be dried after cooking. These, of course, cannot be brought into contact with furnace gases, and must not be kept at a low temperature.

A dryer, therefore, using either exhaust or live steam is the only practical one to be used. This is generally a revolving shell in which are arranged steam pipes. Care should be exercised in selecting a steam dryer which has perfect and automatic drainage of the pipes. The condensed steam always amounts to more than the water evaporated from the material, and, unless removed as rapidly as formed, will soon block the pipes and stop the drying process.

A fifth group ("E") consists of those materials which are composed wholly or contain a large proportion of soluble salts, such as nitrate of soda, nitrate of potash, carbonates of soda or potash, chlorates of soda or potash, etc.

These in drying form a hard scale which adheres to the shell, and a rotary dryer cannot profitably be used on account of frequent stops for cleaning. The only practical machine for such materials is a semicircular cast-iron trough having a shaft through the centre carrying paddles that constantly stir up the material and feed it through the dryer. This machine has brick side walls and an exterior furnace, the heat from the furnace passing under the shell and back through the drying material or out through a stack or fan without passing through the material, as may be desired. Should the material also require a low temperature, the same type of dryer can be used by substituting steam-jacketed steel sections instead of cast iron.

In selecting a dryer for any material the most important feature to be considered is durability. By all means a machine should be selected which by its construction will be free from annoying and expensive repairs. The shell should be of sufficient thickness to retain its shape and resist natural wear for years. If it is supported on tires and wheels, the tires should be made of rolled steel of heavy section and the bearing wheels either of steel or chilled iron ground true; the driving mechanism should be heavy and well designed, and, above all, the machine should be so designed that it will not warp and be deflected by the heat, and so that it cannot get red-hot in any part. The cost of stoppages, to say nothing of repair bills, with a cheaply-constructed and ill-designed machine, will often be as much as the total coal bill. A machine should be selected of ample capacity for the work it will be called upon to do, and should not be forced beyond its rated capacity, or there will be a loss in economy and a decrease in the life of the dryer.

The efficiency of a dryer is the theoretical heat required to do the drying less the loss of heat. These losses are but three, the greatest being the heat carried out by the exhaust or waste gases; this may be as great as 40 per cent. of the total heat from the fuel, or, with a properly designed dryer, be as small as 8 per cent.

The next greatest loss is by radiation from shell or walls. This may be as high as 25 per cent. or as low as 4 per cent. The smallest loss is due to unnecessary heat carried away by the dried material. This may amount, under certain conditions, to as much as 25 per cent. or as low as nothing. Whatever loss there is, however, is generally due to careless operation and not to design of dryer.

A properly designed dryer of the direct-heat type for either group A or B will give an efficiency of from 5 per cent. to 75 per cent., a bricked-in, return-draught, single-shell dryer from 60 per cent. to 70 per cent., and a single-shell, straight-draught dryer from 45 per cent. to 55 per cent.

A properly designed indirect-heat dryer for group C will give an efficiency of 50 per cent. to 60 per cent., and a poorly-designed one may not give more than 30 per cent.

The best designed steam dryer for group D, in which the losses in the boiler producing the steam must be considered, will not give an efficiency of more than 42 per cent., and while a poorly-designed one may have an equal efficiency, its capacity may be not more than one-half that of a good dryer of equal size.

The dryer described for group E will not give an efficiency of more than 55 per cent.

THE NEW BRITISH PATENT LAWS IN OPERATION

There has been much discussion as to the extent to which the recent changes in the patent laws of Great Britain would meet the expectations of those by whom they were devised, and hence the present article, reviewing the actual results, will be read with interest, especially as it has been prepared by a writer who is thoroughly well informed as to the facts in the case. There has been some talk about the advocacy of retaliatory measures by Germany and the United States, but this is wholly premature, and there is every reason to believe that nothing will be done until ample time has been given to enable the ultimate workings of the present British laws to be fully ascertained.—THE EDITOR.

IT is not often that the subjects of patent practice and procedure are dealt with in the general press; but in view of the important changes which have been made in the patent laws in recent years and the work now entailed as between inventor (or agent) and the examiner, it is thought that a few practical remarks on these subjects will be of interest and possibly of value.

The principal respects in which the present patent laws differ from the old laws in force before the act of 1902 are (1) the official search among prior specifications, (2) the relation of provisional and complete specifications, and (3) the requirements as to working. These will be dealt with in order, and in discussing them other features will also require reference.

I. THE OFFICIAL SEARCH

As to the value of this, there can be no two opinions; and, contrary to expectations, in some quarters the official search is, as a rule, far more thorough and exhaustive than was anticipated. It is true that it is by no means unknown for the United States and Continental patent offices to cite British specifications which are not cited by the British Office, or corresponding British specifications can be found to American and foreign citations; but, as a rule, such apparent omissions are explained by points of British law, and are not examiners' omissions. It can, therefore, usually be considered that when the result of the official search is communicated to the inventor it is comparatively thorough and reliable (unless the report is a provisional and more or less cursory one before the full investigation is undertaken), though it must be remembered that it may not always include citations that are not directly to the point, though pertinent, whereas a privately undertaken subject-matter search should go much further. As soon as the report is received (as a rule, printed specifications which are out of print are reprinted, if cited in an examiner's report) it becomes necessary to consider how they can be avoided and the invention differentiated from what has been done before; and it is in this work that the skill of a patent agent is most apparent if the case becomes at all difficult. In fact, it is fairly safe to say that the chances of the inventor who is his own patent agent going astray in this work are at least ten to one.

Opinions are divided as to whether the examiners are strictly within the law in their attitude towards prior specifications. The present tendency appears to be towards requiring a disclosure of so much of what has been done before as will enable the actual value of the new invention to be appreciated; whereas it may reasonably be contended that it should be sufficient to word the claims so that the subject matter is clear. It

is no part of an inventor's duty to tell the world what other people have done, though it is often a good way to differentiate and point out the good points of his own invention.

It is, however, not always easy to satisfy the examiner that there is sufficient differentiation by the wording of a claim, though it is desirable that this policy should be adopted as far as possible; and, as a rule, the objection can best be overcome by an acknowledgment of the state of the art. Several ways of doing this are employed, according to the seriousness or otherwise of the citations.

In some cases the introduction of the specification can be altered to indicate what is required, either by stating what has been done (in terms, but without specific reference to prior specifications, which should be avoided if in any way possible), at the same time pointing out the weak points, and so leading up to the new invention, or by stating that "this invention refers to apparatus for * * * of the kind in which * * *," thus covering the old features as characteristic of a class of apparatus to which the invention relates.

In other cases the specification and claims can be left untouched and a disclaimer inserted in the form of "I am aware that * * *." This may be left either as a bare statement, or may be followed by remarks pointing out that in the prior specification something is done in such a way, whereas the new invention does something else.

Occasionally a specific reference to prior specifications may be profitably made; but in such a case there should be good reason for this, and it is not usually a desirable course to be followed.

All these methods have their good points, and they also have their bad ones. Thus, although it is quite possible in many cases to differentiate from what is old by the wording of a claim, this is not suitable when an invention really includes old items; and it is usually necessary, if a combination is to be covered, to acknowledge what has been done as regards the old items. Whether this is strictly required by the law is another thing, for if an invention consists of a combination it is not anticipated by disconnected items or by an incomplete combination, or one which includes some items only with one or more non-pertinent items. There are many cases where the real invention lies in producing the combination. The items may be old, but it is the way they are combined and matters of that kind which constitute the real value of an invention, and for that reason it is sometimes asking more than is legitimate to require acknowledgment of incomplete or different combinations because some of the items correspond. In other cases it is advantageous to indicate the development from what is old, or to point the differences, by referring to previous practice, and if only certain differences require acknowledgment it is not often that acknowledgment need be grumbled about. On the other hand, it is good policy, in many cases, to object to such acknowledgment, though it may necessitate joining issue with the examiner; and in such cases the remedy is to apply for a hearing before the comptroller or his representative. This is a kind of appeal from the examiner's decision, and it is fairly safe to say that the decision will go with the applicant if he can make out a good case. In fact, in many instances the examiner himself suggests this course, for the comptroller may be able to accept amendments which the examiner considers he is not entitled to accept on his own responsibility. There is a tendency, however, in some quarters to rather abuse this privilege of calling for a hearing, especially as no fee is required. It may be well in some ways to do nothing except what is unavoidable, and to amend only as required by the highest authority; but it is far better, if possible, to settle matters with the examiner, reserving

hearings for appeal purposes if matters come to a deadlock, or if the examiner seems to be asking too much.

It appears to be desirable that, at all costs, an official reference to prior specification should be avoided. As the law stands, it should be sufficient, if matters become serious, if a specific reference to prior specifications is made by the applicant, and such acknowledgment may really indicate strength, because of the knowledge of what has been done that is thereby indicated, whereas official reference almost amounts to a "black mark"; but in the writer's opinion it should often be good policy to use claims as broad as is considered desirable, and to allow official endorsement, leaving the interpretation of the actual invention for decision by the courts, if the subject matter should ever be contested. By this method the applicant has at least made his claim wide, and it is always possible to amend to make it narrower when proved necessary; whereas if the claims are narrowed and it should be proved later that official requirements are not fully justified, it is not possible to broaden the claims to what may readily be within the rights of the inventor. However, while official endorsement is generally considered to be a "black mark," it is desirable to avoid such endorsement, and in practice the comptroller has proved very reasonable in this respect.

II. THE RELATION OF PROVISIONAL AND COMPLETE SPECIFICATIONS

Since the commencement of official searches among prior specifications the matter of disconformity between provisional and complete specifications has become rather awkward in many cases, and the act of 1907 has, therefore, very wisely provided for this matter. As described in the provisional specification, the invention is often somewhat crudely set forth, while considerable development may take place by the time the complete specification is filed. As regards the relation of the two specifications in reference to the question of legitimate development, the state of affairs is not altered in ordinary cases; there is still the question of what constitutes legitimate development and what is new invention. But it is in the matter of the effect of citations that the new provisions are valuable. As described in a provisional specification, an invention may be shown by the official search to contain nothing new; but the complete specification, describing the developed invention, may include good subject matter. Without special provision, the inventor may be precluded from proclaiming what good matter he has, because he did not include it in the provisional specification. By the new act, however, in such a case the application may be re-dated as of the date of filing the complete specification; and although this means risking what has been done between the dates of filing the two specifications, it enables what subject matter is claimable to be maintained. For some time past, however, this procedure was countenanced under the 1902 act, though not provided for, and therefore the 1907 act simply makes this strictly legal.

The new act, however, goes even further than this, for it enables subject matter which might be questionable development of a provisional description to be covered in a divisional application from the main application, and bearing date from the filing of the complete specification; and this should, therefore, be a very useful provision.

III. WORKINGS

Before the 1907 act was passed a great deal was said about the beneficial results to national industry that would result from the new requirements as to working; but it is somewhat remarkable that the act appears to be coming up to anticipations in this respect. On all sides one hears of foreign firms who have supplied

the English market from factories abroad, making arrangements for an establishment of works in Great Britain, or making arrangements for the manufacture of their goods by firms here; and if half of these are realized industry will very appreciably benefit. Yet the law does not say that all patents must be worked in Great Britain, nor does it define adequately what conditions of working will suffice. It only states that within four years (from August 28, 1908) any one can apply for the revocation of a patent on the ground that the article or process is manufactured or carried on exclusively or mainly abroad, and the matter then rests with the comptroller to decide whether this accusation is justified and to require compliance on penalty of revocation. There is so much that is still indefinite and the requirements are so vague (the result of a successful suit of this kind must provide for compliance with the law before revocation can take place) that it is difficult to understand why so many preliminary steps are being taken. It has yet to be decided what are the qualifications of the person who can bring such a suit. Surely he must have some interest to give him standing, for it hardly seems desirable that anyone can do this! Again, it has to be settled what is adequate working, both in view of what is done abroad and in view of requirements in Great Britain, and this matter will prove a very difficult one to settle. It will have to be decided what amount of manufacture is a legal working in cases where, for example, there is no substantial field for business with articles that are very successful abroad, though what is done may be quite worth a patent. And when these matters are decided a very different complexion may be given to the question. Furthermore, there is the loophole of commencing but not continuing working on the prescribed scale to comply with the law. It is true that the comptroller will possess the power to revoke a patent forthwith, but it is hardly reasonable to suppose that such power will ever be exercised to any appreciable extent, and then only in extreme cases. Consequently, this matter is so much "in the air" that the real value of these provisions must be left for time to show. What is being done is a good sign, and there are evidences to show that the result will be very advantageous. On the other side, however, there is a tendency of some foreign inventors to drop British applications, because of the fact that the requirements may become more onerous than business justifies. This fact by itself may not be industrially important, but there are new signs that certain other countries are preparing to retaliate, and, if so, British inventors and firms may be placed in a similar dilemma as regards use of their patents abroad.

BARRIERS TO INTERNATIONAL TRADE

A STUDY OF THE PROBLEMS AT THE PORTS OF LIVERPOOL AND NEW YORK

By Lewis M. Haupt, C. E.

It is now beginning to be recognized that serious limitations to the further developments of ship-building exist in the condition of the entrances of some of the principal harbours of the world. Unless suitable channels are provided and maintained for vessels of the largest size, the work of the marine architect and engineer is bound to be hindered and prevented from attaining its most desirable results. Taking the ports of Liverpool and New York as exercising a controlling influence upon transatlantic traffic, Professor Haupt examines the conditions acting to obstruct the harbour entrances, and points out methods by use of which the formation of bars may be prevented and suitable channels maintained. The present paper discusses the port of Liverpool, and in a following article the harbour of New York will be examined.—The Editor.

I.—THE PORT OF LIVERPOOL

GEOGRAPHICAL or natural advantages do not always determine the locus of great commercial ports. The line of least resistance in transportation is that of least cost, and this, in turn, is a factor of greatest earning capacity, of which the principal element is time.

In view of the enormous sums of money which are expended in the effort to reduce the time of crossing the ocean by only a few hours, it is essential that any such advantage shall not be neutralized by having to await high water before entering the port. Such detentions arise from the existence of the sand bars which are to be found at the entrances of nearly all harbours or inlets which indent alluvial shores and over which the ruling low-water depths seldom exceed 15 feet in their natural condition.

These ocean barriers have constituted a very serious obstacle to the use of the most economical dimensions of vessels, and their removal has been desired by all maritime nations for centuries, so that every conceivable art and device has been applied in this irrepressible conflict with the sea.

Inch by inch has been recovered by extensive jetties, supplemented by dredging; yet the demands of traffic are ever crying out for more water and for deeper and wider channels. Not satisfied with 20 feet, they demand 30; and having secured 30, they now call for 50. The vessels of a few decades ago could be stowed in the holds of the present leviathans of the deep.

This development is admirably shown in the graphical exhibit contained in the paper of Mr. Brysson Cunningham in the issue of this magazine for December, 1908.* The curve of progress there drawn is determined from the record of facts and carried forward to 1920, when it reaches the 1,000-foot limit in length. But greater length and beam require greater depth for strength and stability, and the end is not yet.

Hence it is that no fixed dimensions are prescribed for the great canals or channels in the acts authorizing their construction, but they are made dependent upon those of the vessels. This unfortunate ambiguity leads to continual increase in size and cost, involving changes of plans and enlargements of all accessory and permanent works, for the vessels in many cases will have outgrown the channels long before the latter can be completed.

The operation of American and European politics in harbour improvement may well be illustrated by examining the efforts which have been made to remove the bars obstructing the entrances to the great international harbours of Liverpool

* Brysson Cunningham; The Influence of Recent Developments in Size and Speed of Steamships on Port and Harbour Accommodation. Cassier's Magazine, December, 1908, pp. 313-326

and New York, at both of which the largest sea-going vessels have been obliged, of late years, to await high water to clear with partial cargoes.

Under the Admiralty laws of Great Britain her harbour improvements are placed in the hands of twenty-eight commissioners, selected from the residents having the largest coal interests at stake, and known as the "Mersey Docks and Harbour Board," created by act of Parliament in 1857, to have control and management of the channel and docks at Liverpool and Birkenhead. Of these twenty-eight members, twenty-four are elected by the dock ratepayers and four are appointed by the conservancy commissioner of the river Mersey. Each member is elected for four years and is re-eligible to office, but without compensation. It is a trust, operated without thought or purposes of private gain, and its revenues are applied to increase the facilities and prosperity of the port. Its management has been eminently liberal and successful, so that it has acquired an enormously valuable property, bonded to the extent of nearly $100,000,000, from which the total receipts during the fiscal year ending June 30, 1908, were $6,766,-588.

The great tidal fluctuations of the Mersey have made it necessary to construct an extensive series of wet-docks with gates, that the vessels may handle cargoes from a fixed stage; but that they may enter or leave the port over the bar, which, under normal conditions, had only 11 feet of water on its crest at low tide, has proven to be a very different problem. This is the key to the port which the Harbour Board is still working at in its endeavour to meet the present demands of navigation. Its history is worthy of careful study.

HISTORIC

The earliest authentic chart, made in 1689, under William III., showed only two channels, known as the "West" and "Formby" channels, and it was not until 1833 that complete surveys were instituted. These comparative charts indicate a shifting of the axis of the channel, within certain limits, due to tides, winds, waves and currents acting—sometimes in conjunction, at others in opposition—upon the movable sands of the bar, which cover an area of about 25 square miles, bare at low water.

The crest of the bar crossing has moved seaward between 1868 and 1895 some 1,400 yards, giving an average of 155 feet per annum; while the depth, which some years previously exceeded 12 feet, was reduced in 1874 to less than 8, rendering it unnavigable to tugs even at low water.

Under these fickle conditions of depth, location and alignment attempts were made as early as 1838-9 to improve the navigation by "harrowing" across the new channel then opening, but with unsatisfactory results. The currents, however, by their natural action, opened this cut, which became the principal entrance, known as the "Victoria Channel," for many years.

Up to the year 1885 the main reliance for the amelioration of ocean bars was placed upon the use of two jetties, supplemented by dredging operations; but the introduction of the system of hydraulic dredging, as invented by A. B. Bowers, C. E., of California, at that date, has revolutionized the art and led to great improvements in channels at much less cost; yet, without regulating works to protect the cuts in the open sea, it is manifest that the depths must be but temporary, and that where the movements of the silt are large the capacity of the plant must be very great to keep pace with the sedimentation. To depend upon dredging at the mouth of a sediment-bearing run like the Mississipi, which discharges 440,000,000 cubic yards annually into the Gulf, is manifestly hopeless; and although the Mersey bar has a relatively small quantity of silt in transit, its control, even with

the largest plant in existence and at the least cost, is one of great concern to the Board.

The present depth of 28 feet has been secured only after persistent efforts, and the gain has been an increase of one foot only in the past eight years; yet the encroachments of the drifting sand banks upon the channel are such as to have reduced its width nearly 500 feet in the past year and have rendered it tortuous and more difficult to navigate.

The experience of the past eighteen years with dredges on the bar under the most skillful and economic management has led the chief engineer, Mr. Anthony G. Lister, to the conclusion "that the dredging method has its limitations and cannot provide for every contingency which is likely to arise. Further experience will, without doubt, throw more light on the relative merits of the two systems. It is now considered that the scale of the improvements contemplated in 1890 is insufficient for the immediate future and that the dredges that have been so usefully employed on this work for the last twelve to fourteen years are approaching the limit of their useful service."

It would seem, at first glance, that, if the capacity of the plant were equal to the amount of the littoral drift crossing the bar and channel, there would be a possibility of maintaining it; but the actual results here tell a very different story. In 1881 Mr. Russel Aitken proposed improvement by dredging, and estimated that, to obtain a 30-foot channel, 300 yards wide at low water, spring tide, from the sea at Liverpool, would require the removal of some 9,000,000 cubic yards, which, at 8½*d.* per yard, would cost £320,000. In commenting on this project, *Engineering* says: "The 30-foot channel has not yet been made, although the work has been in hand continuously from September, 1890, to the present time (May, 1907); and up to the date of the latest return, the end of 1905, the total quantity of dredging on the sea channel and bar reached upward of 70,000,000 cubic yards, and in that particular year, although 7,500,000 cubic yards were dredged, this quantity failed to maintain the channel."

Had this cost 8½*d.* per yard, the expense would have exceeded one and a quarter millions a year; but the great economy of the hydraulic plants reduced the cost to about 1¼*d.*, or about $180,000 per annum.

This work was begun in 1890, when two of the hopper-barges of the Harbour Board, having a capacity of 500 tons each, were fitted up as dredgers and operated on the bar, where it was found they could fill their bins in from 20 to 25 minutes under favourable conditions. Between September, 1890, and June, 1893, they removed about 2,500,000 tons of sand and increased the depths from 11 to 18 feet, which gave a navigable channel of 26 feet for about eighteen hours by means of the tides. But this increase was all secured in the first eighteen months, or by March, 1892, after which date it appears that the inflow of material equaled the capacity of the dredges, which were kept at work continuously, without substantial gain in depth, and much larger dredges were built to meet the situation.

In other words, in cutting through the narrow crest to a depth of 7 feet, there were removed 775,430 tons in the year and a half; but in the remaining sixteen months 1,656,290 tons were excavated without perceptible increase, indicating (if the width remained constant at 1,000 feet) that the stability of the bar was disturbed and that the sand was flowing in at the average rate of about 100,000 tons per month, or 1,200,000 per annum. The unexcelled efficiency of the new dredgers *Brancker* and *G. B. Crow*, which were installed in 1893 and 1895, soon increased the depths, so that by June of 1895 there had been excavated 10,282,800 tons, creating a

channel of 1,500 feet in width, "with a minimum depth varying from 20 feet at its sides to 24 feet along its centre line."

This increase has been continued up to 1899, when it reached 27 feet, and in June, 1907, it was reported to be 28, or a gain of only 1 foot in the last eight years. The report of the Dock Engineer for the year ending July 1, 1908, states the total excavations since 1890 to have been

This table illustrates in condensed form, the enormous increase in the quantity of spoils to be removed annually and the inability of the present plant to provide the 30-foot depths required, so that in addition to the proposed revetment of one of the banks, it is also intended to make provision for vessels of 1,000 feet in length by 40 feet in draught by the construction of a dredge of 10,000 tons per hour capacity, hav-

EXHIBIT OF RESULTS SECURED BY DREDGING AT THE BAR OBSTRUCTING THE ENTRANCE TO THE PORT OF LIVERPOOL.

Dates, Years.	Depth, Feet.	Excavated, Tons.	Total Tons.	The Depths are Referred to Low Water of Ordinary Spring Tides.
1833	12	....	....	Dredgings of 600,000 tons were dumped into river for upwards of twenty years.
1863	10 to 13	....	....	In the new or "Victoria" channel on bar, channel shifted to North called "Queen's."
1874	7 to 8	....	....	In 9 years shoaled from 3 to 5 feet.
1881	Vary 7 to 17	....	....	Dredging proposed by Russel Aitken.
1882	..	....	....	Estimated to require 9,000,000 cubic yards for a 30 foot depth 300 yards wide, at cost of £320,000, but was not begun until 1890.
1890	11	79,650	....	After four months with one 500-ton dredge.
1891	..	577,350	....	Two 500-ton dredges, Nos. 5 and 7, at work.
1892	..	1,069,030	....	
1893 June	18	....	2,438,710 Total to June, 1893	Cut 1,000 feet wide, 16 feet on edges, 18 feet at center.
to Dec. 31	..	2,288,090	4,014,120	The "*Brancker*" of 3,000 tons set to work.
1894	20	5.547,110	9,561,230	The cut was 1,000 feet wide at 17 feet and 500 feet at 19 feet. Vessels of 20 feet draught could enter at any stage.
1895	24	4.781,270	14.342,500	To June, cut 1,500 feet wide, 20 feet at edges. Another large dredge placed on work and two small ones removed.
1896	...	7,662,590	22,005,090	
1897	25	....	....	The tender "*Alarm*" added to the fleet and "*Brancker*" withdrawn.
1898	..	....	41,240,360	
1899	27	....	....	Channel 1.500 feet. "*Brancker*" returned.
1900	24	7,600,000	....	Foreign tonnage 10,949,000
1901	25 to 27	9,000,000	....	
1902	25	....	....	
1903	25 to 27	....	....	
1904	26	....	....	
1905	25¾	10,019,000	....	Taylor's bank channel shoaled 2 feet; narrowed, 90 yards. Foreign tonnage, 16,900,000; coastwise, 25,000 000.
1906	27	4,797,500	....	
1907 May to Dec.	..	11,977,000	108,675,570 115,625,000	From bar, 35,617,040; Crosby Channel, 44,340,810; Main Channel 28,717,720 tons.
1908 July	28	....	121,424,470	From bar, 36,658,240; main channel, 84,766,230 tons.

121,424,470 tons, and adds that "the condition of the bar has been fairly well maintained, * * * the ruling depth at the present time on the west side of the channel being about 28 feet; on the east side, however, * * * the depth is somewhat less. The ruling depth in the Crosby channel may be taken at 27 feet, though the depth adjacent to the line of buoys is somewhat less."

The actual situation is briefly shown in the above table of the data in hand:

ing about three times the power of any existing machines, to handle much larger quantities, and work at 10 feet greater depth.

The chief engineer has correctly stated that "the largest and most up-to-date suction dredges have been employed in the work, but the silting still goes on, and the maximum depth of 28 feet at low tide is with difficulty maintained. The channel at Askew Spit is being considerably narrowed by silting, and there is a possibility of the navigation of the

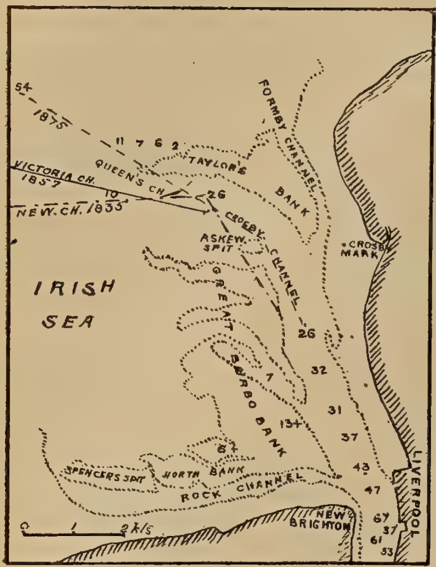


FIG. 1.—LIVERPOOL BAY

main channel becoming very dangerous indeed."* The Crosby is the main channel, its outer three miles being designated as the Queen's channel. It passes through banks of sand which were formerly dry at from 6 to 7 feet above low water; but the Little Burbo bank has disappeared since the dredging began, indicating a drift channelward.

Farther up other important changes have taken place. There has been trouble along the outer (northerly) edge of Crosby channel, which is being carried away by the tide, and a spit is running from the inside edge across what used to be the deep channel, making a very awkward bend; or, in other words, "the Askew Spit has advanced northward with the recession of the concave bank, resulting in a reverse curve lower down," requiring dredging on the north side of Queen's channel just inside of the bar of 6,063,700 tons, which is greater than at any other point. In this extremity it is designed to place a training wall on the concave bank, to increase the scour near Askew Spit and to supplement the current action by the new dredge intended to lift 10,000 tons of sand to a height of 70 feet at high water in 50 minutes.

In commenting on this wall, *Engineering*, of March 15, 1907, states that "at Liverpool the step proposed is considered to be bold and hazardous. The hope appears to be that the training wall will cause a widening of the deep-water channel. Some of the leviathan liners, when outward-bound, draw over 30 feet, and some of the patches of sand carry only 28 feet.

"The chief trouble of late has been the silting of the Crosby channel near

* See *Marine Review* of Dec. 3, 1908, p. 51.

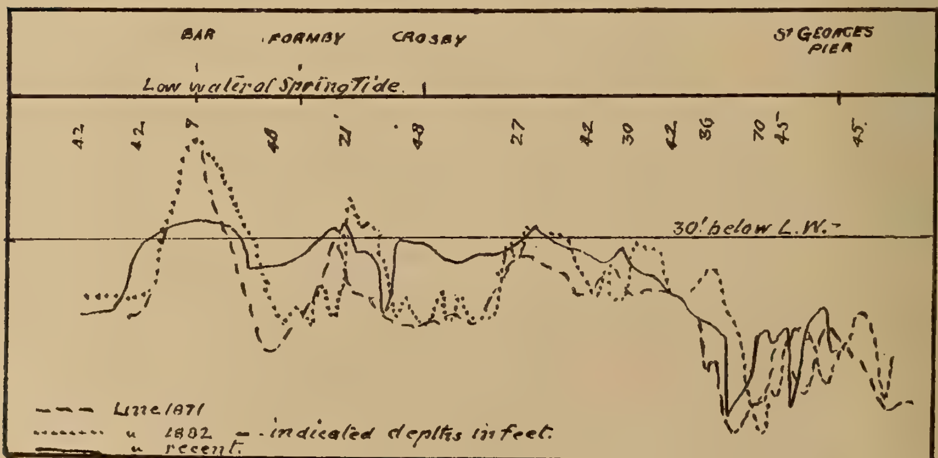


FIG. 2.—PROFILES OF BAR AND CHANNELS AS INDICATED

Askew Spit, so that its width has been narrowed in twelve months by nearly 500 feet."

To give a clearer conception of the changes which are taking place and the probable results to be effected from the revetments, the accompanying cuts are reproduced from our contemporary, *London Engineering.*

Fig. 2 indicates the extensive shoaling of from 10 to 13 feet for abouts, measured in a southwesterly direction from the beach mark on the foreshore of the urban district of Little Crosby, known as Crosby beach mark, and terminating at a point situate 5,360 yards or thereabouts, measured in a westwardly direction from the said Crosby beach mark.

"The works * * * will not exclude, impede or interrupt the tidal or other waters of the river Mersey."

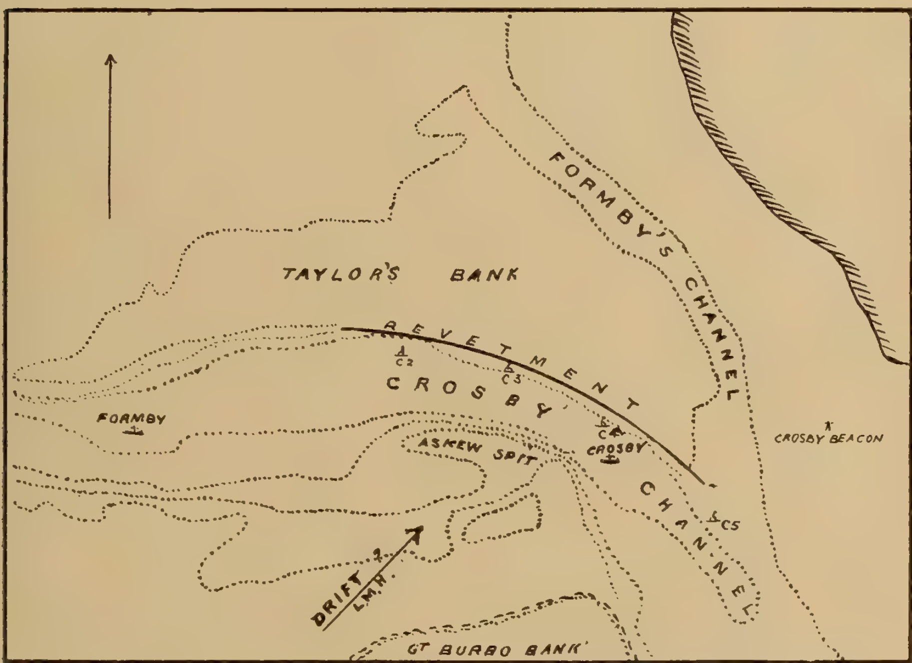


FIG. 3.—LOCATION AND CURVATURE OF THE REVETMENT ON NORTHERLY FACE OF CROSBY CHANNEL

several miles inside of the bar, as indicated by the full line marked "present" and the broken one of 1871, or the dotted one of 1882.

The notice of this work, as published on January 17, 1907, describes it as follows (see Figs. 3 and 4):

"A stone revetment to the height of mean low-water mark or thereabouts on the southerly face of Taylor's bank, in Crosby channel, in the estuary of the river Mersey, or Liverpool bay, commencing at or near the southerly end of Formby channel at a point situate 1,370 yards or there-

Fig. 3 shows the location and curvature of the revetment on the northerly face of the channel, and Fig. 4 the cross-section of the mound of rock as originally placed and as assumed after its settlement. Its total depth will be about 2½ miles.

THE PHYSICAL PROBLEM

It is beginning to be recognized by engineers that the shifting of channels and bars is primarily due to the drifting of the sands, agitated by the breakers, especially during flood tide, and that if these en-

croachments can be prevented, sand, having double the specific gravity of water, the channel will not deteriorate.

The solution of the problem of improving a channel by natural agencies must give due consideration to the various causes tending to effect the observed changes. These involve not only the entire regimen of the estuary, but of the tidal phenomena of the adjacent waters.

Thus it is seen that Liverpool is at the apex of a re-entrant bay of the Irish Sea, which is filled by the flood tides of the Atlantic through the wide St. George channel on the south, and the narrow North channel on the north. The location of the co-tidal lines for high water are shown on Fig. 5 for each hour, and the

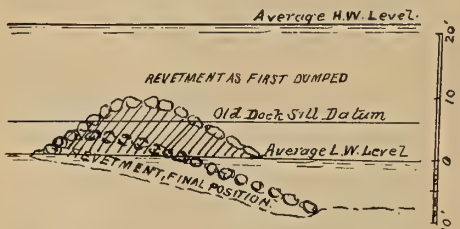


FIG. 4.—CROSS-SECTION OF REVETMENT IN CROSBY CHANNEL IN ITS ORIGINAL AND ITS FINAL POSITION

heights of the tides at various points are also indicated in feet along the coasts. It is evident from this chart that the contour of the shore line has a very material effect upon the amplitude of the tide, as well as upon the velocity of its transmission.

On the English side of the basin they are from two to three times higher than on the east coast of Ireland, while the travel of the crest from V. to XI. hours through the St. George channel is about double that passing in from the north. It thus happens that the southerly tide is the dominant one, and that it is not neutralized to any great extent at Liverpool, where the oscillations are the largest, ranging from 19 feet at neap to 33 at equinoctial, spring tides. Its velocity is about 30 miles per hour, and the current velocities over the bar range from 1.6 to 3.4 statute miles per hour.

This tide, after crossing the 25 square miles of sand banks, passes through the neck or gorge of the Mersey, which is less than a mile in width, from 50 to 66 feet at low water in depth, and 5 miles long. It pours some 500,000,000 cubic yards of sea-water, with its suspended silt, into the 40 square miles of the estuary as a reservoir. At the turn of the tide this process, augmented by some two to three million yards of fresh water, is reversed; but the effluent waters in their escape are trained through the neck of the funnel and out over the bar along the lines of least resistance, as determined by the barriers erected by the external forces. They are divergent, and soon become impotent to maintain the depth required by displacing the heavier sand. To apply them effectively, without interference with the tidal influx, is the vital problem, and for its solution a diagnosis must be made of the structural lines of the bar as indicating the resultant activity of the forces.

Tracing the crest or line of least depth, it is found to be very sinuous (Fig. 6), the outward flexures indicating the relative preponderance of the ebb, and the inward, of the flood tides. The slopes, as revealed by the cross-sections of the banks, also furnish valuable indices to the directions of the drift, the flatter slope being on the side of the propelling force, the steeps on that of the overfall, excepting in the case of undermined banks. The profiles of the channels (Fig. 7) are also suggestive as to their origin, whether from flood or ebb tide. These features may be supplemented by the record of changes as made by competent hydrographers.

From the British Admiralty chart of 1885 of Liverpool Bay, made by Commander G. H. Hills, R. N., reduced charts (Figs. 6 and 7) have been prepared, showing the topographic conditions at that date be-

fore dredging was begun, upon which the alignment of the principal channels, their cross-sections at mile intervals, and profiles, as well as the crest of the bar, are indicated.

its gorge and opens into the land-locked tidal basin beyond and the entrance to the Manchester canal.

The flood tide rolls its enormous volume up and over the restraining

FIG. 5.—COTIDAL LINES OF THE IRISH SEA

In a general way it is seen that the shore lines from the mouth of the river Dee at Hilbre Point to Formby Point forms a funnel, of which the orifice is the river Mersey, which is about a half mile wide at enceinte of sand, which, in places, rises to 19 feet above low-water, and, by the reaction from the shores, maintains the two shallow flanking channels known as "Rock" and "Formby," the slopes of which rise

as they approach the entrance. The outer sector, 8.5 miles distant from the mouth, has a perimeter of 1.35 miles in length and a low-water sectional area of 800,000 square feet.

Until recently no attempt has been made to utilize the natural forces of the tides and currents for the improvement of the channel, as it seemed feasible to dredge the cut

FIG. 6.—PLAN OF LIVERPOOL BAY, SHOWING ITS HYDROGRAPHIC FEATURES

The middle sector, 4 miles out, is 7 miles long, with only about 171,000 square feet of section, while the one at the mouth proper contains about 150,000 square feet, which is still further reduced to 100,000 square feet at the gorge of the river channel 3 miles within.

through the outer bar by the removal of some 9,000,000 cubic yards in place, and thus open the port to all the world; and yet, after the eighteen years of masterful effort by the most effective and economical plant in existence, the result is such as to warrant the effort to use regu-

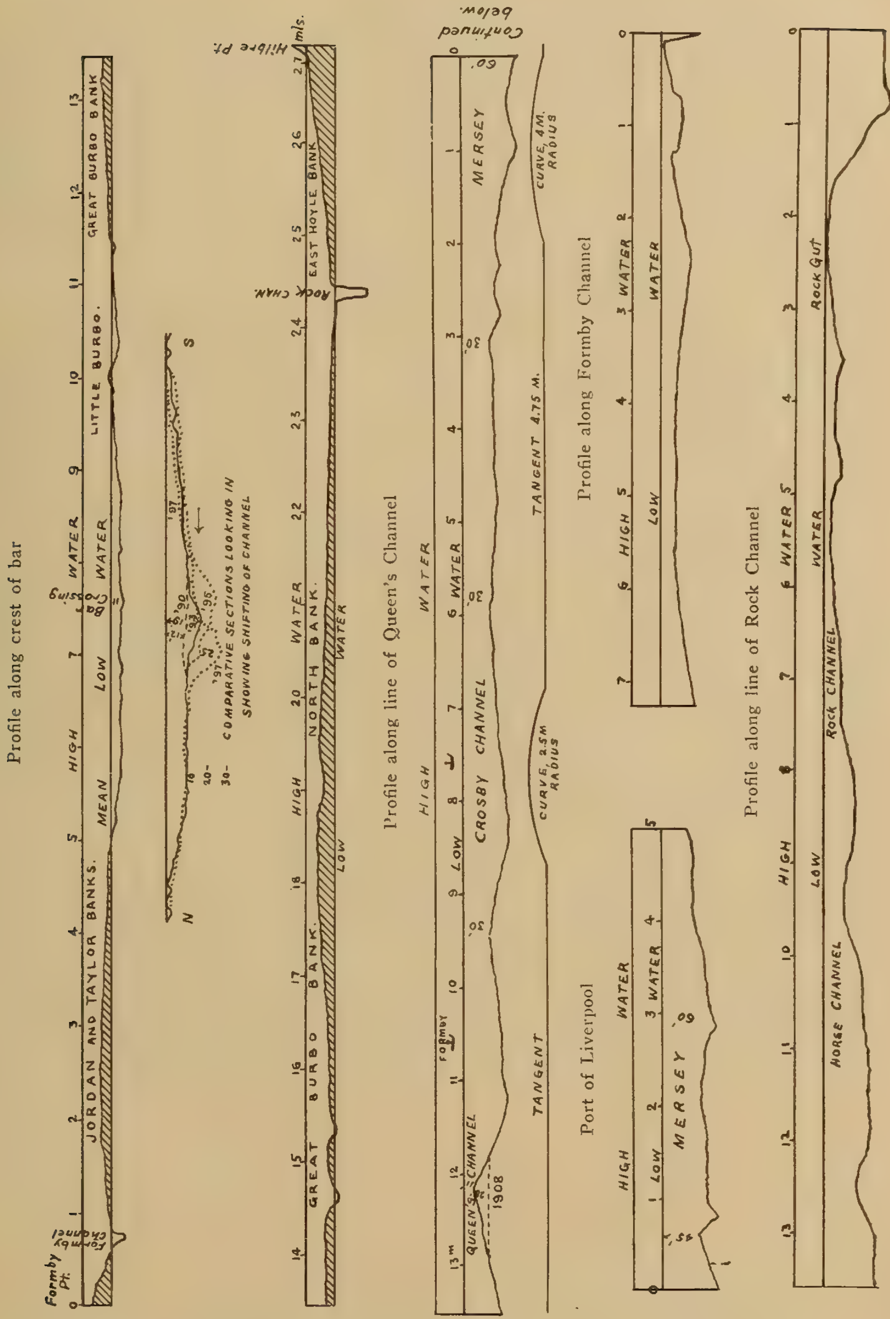


FIG. 7.—COMPARATIVE PROFILES OF THE VARIOUS CHANNELS OF LIVERPOOL BAY

lating works, which are to be placed, apparently, on the opposite bank from that which supplies the drift.

In this connection it may not be out of place to suggest that the invariable effect of a concave revetment will be to scour at its foot, and to cast the material across and upon the convex bank, which, in this case, would doubtless increase the deposits on the southerly side, making the channel deeper, but narrower and more crooked, while not arresting the drift fed to it from that source at Askew Spit. Numerous precedents might be cited if space permitted.

The main bar has been disintegrated by the enormous amount of dredging, and its effects are manifest in the comparative sections (Fig. 7) along the outer five miles of the crest, where it appears the southern flank has gained in height and the northern has not materially changed, while the dredged channel of 1905 has been filled and driven 3,000 feet north in two years. It would seem, from this old survey and the reported changes which have taken place subsequently, that a training wall of something more than a mile in length would prove a necessary and effective agent in opening and maintaining a 30-foot depth at this vital point without pushing it seaward.

The typical forms of the bars and channels, their cross-sections, areas, widths, slopes, profiles, velocities of currents, prevailing winds, amplitudes of tides and character of bed, are all factors which are closely related to the proper solution of this interesting international problem; but the limits of this paper will not admit of their further technical consideration.

Suffice it to say that the experience gained at various alluvial inlets the world over indicate that some more efficient devices than dredges must be applied to meet the demands even of the great leviathans of the present day, and that the "ounce of prevention" rather than the "pound of cure" will prove in the end to be the most economical and efficient remedy.

A clearer idea of the relations between cause and effect may be obtained from the relief model, showing the relative positions and forms of the channels and shoals as exhibited by the illustration (Fig. 8). In this model the vertical scale is about 70 times the horizontal, and the contours are one fathom (6 feet) apart. The figures indicate the depths in fathoms below low tide and the heights in feet above the same datum.

The influence of the Hilbre Island ridge (1½ miles long) in the estuary of the river Dee is manifested in deflecting the ebb tides, and, by its reaction upon them, cutting out and maintaining the "S-shaped" channel about 2,000 feet wide, with a maximum depth exceeding 50 feet, and having a length of over 5 miles at the 30-foot contour. Thus Nature furnishes evidence of what a portion of this tidal energy may accomplish. The material excavated by the currents from this serpentine trough is ejected on the opposite or East Hoyle bank, which rises to 22 feet above low water, or about 11 feet below equinoctial spring tides. This bank of sand, in turn, operates as a current deflector to construct and maintain the East Hoyle bank, which again swings the effluent currents westward, and, in spreading over the seaward sector in open water, leaves the residual crossing-bar, with its resultant low-water depth of about 14 feet, in a state of nature. Another portion of this discharge from the estuary of the Dee, which is 5 miles wide, is reflected to the westward by the deposits of West Hoyle, which have created, by reaction, a deep pool, extending to 12 fathoms under its lee, thus revealing the effects of these sandy barriers of heavier material upon the moving currents of the tides. The East Hoyle Spit, therefore, owes its existence mainly to the presence of Hilbre Island, and forms a cover for the 5-mile stretch

FIG. 8.—MODEL OF THE BAR AND CHANNELS IN LIVERPOOL BAY

of Spencer's and North banks, which flank the Rock channel, created by the concentration of those tides by the foreshores as they approach the mouth of the Mersey and enter the port.

The enormous deposits of the Great Burbo bank are also caused by the action of the flood-tides, waves and winds in driving the sands into the re-entrant angles and building this natural rampart to check their advance, reaching its greatest altitude of 19 feet on the edge of the eroded ebb channel. The breaches midway between North bank and Askew Spit are directly traceable to the influence of the concave bend at the outlet of the Mersey, where the axis of the curve has a radius of 4

miles and a length of 2, thus increasing the intensity of the ebb forces over this section of the enciente. A similar action is observable between the Askew Spit and Little Burbo, due to the curvature caused by Jordan bank, which deflects the currents westward. The encroachments of Askew Spit indicate a preponderance of the flood forces which should be arrested *in situ,* and the tendency of the left flank of the ebb channel to creep northwardly should be so restrained that the activity of the flood may be diminished and of the ebb increased at the same time. Thus the agencies producing deterioration may be utilized for the amelioration and maintenance of a fixed and capacious navigable channel.

This brief diagnosis may serve to point the way to an effective and economical means of so removing this serious obstacle to international trade as to result in its accomplishment at a cost which should be well within that of the capitalized expenditures for the creation and maintenance of the proposed 40-foot channel by dredging. It is based upon the physical features of the submerged bed of the ocean (in 1885), which is the chronographic resultant of all the forces which have moulded it in past centuries.

A resurvey of the effects due to the recent extensive dredging and dumping operations should, however, be made to indicate present conditions of the bar and channel as the basis for a reliable estimate of cost.

TRANSPARENCY OF METALS

By J. Horton

IT may come as a surprise to many interested in the working of metals to know that, under any circumstances, metals can be obtained in a transparent state. It is well known that metals are usually opaque, not only to light but also to Rontgen rays, and it is owing to this property that needles or foreign bodies can be perceived in the human body by the surgeon using the X-Rays. Even the finest obtainable sheets of silver, copper or aluminium are quite impervious to light, except through any small cracks due to the process of manufacturing. It is true that, by means of chemical precipitation, or in films obtained by electrical processes, sufficient thinness is secured to allow of light passing through a film of metal. But with material which is manufactured commercially, as by rolling or hammering, the only case of transparency hitherto known is that of gold, which, when beaten into sheets of about one three-hundred-thousandth of an inch in thickness, transmits a characteristic green tint. About fifty years ago Faraday showed to the Royal Society that thin sheets of gold and silver when heated on glass plates became transparent; but the question had not been further investigated until recently, when it was first undertaken by Mr. Beilby, F. R. S., and, more recently, by Professor T. Turner, at the University of Birmingham. It is found that with gold a change takes place at about a just visible red-heat, when the particles of the metal are drawn together, with the result that white light passes between them, and the metal presents a transparent appearance. It was assumed that a similar action took place with silver, but up to recently no experimental evidence was forthcoming as to the nature of the change which occurs. The transparency in the case of silver in properly prepared samples is really remarkable. The glass plates become almost as transparent when covered with silver leaf about one-hundred-thousandth of an inch in thickness as when no matter is present.

It has been shown by Professor Turner that this action commences at a heat of about 240 degrees centigrade, and that it only occurs in the presence of air or oxygen. It does not take place if the silver is heated in a vacuum, or in hydrogen, or any other reducing atmosphere. Curiously enough, silver does not get any heavier when heated in this way, nor does the oxygen that is necessary for the change alter in bulk, so that at first sight it may appear difficult to account for oxygen being necessary. But it is suggested that there is a temporary combination of the oxygen with the silver which is rapidly again broken up. It is easy to show that the silver, though almost invisible, is still really there as metal. Perhaps the easiest way is to place a sheet of silver on glass and heat them together until the metal becomes transparent. Then by writing on the metal with an agate stylo it will be found that the characters are clearly outlined in bright silver on the glass, and the writing in such cases is as clear as on ordinary writing paper or on a slate.

A new observation in connection with these experiments has been that thin leaves of copper become quite transparent when heated in air to a suitable temperature and then transmit light, the colour of which varies

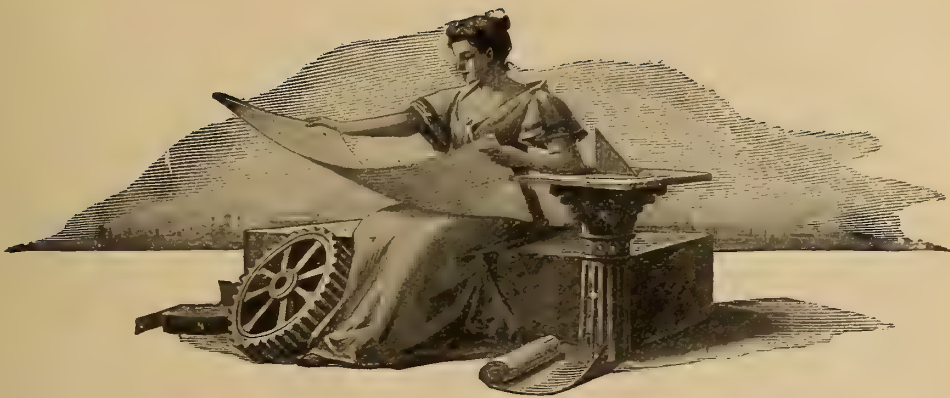
according to the temperature which is being used. The copper is not affected if heated in coal gas, or away from oxygen. But when a very small quantity of oxygen has been absorbed by the copper, the metal transmits a beautiful emerald-green light, and this becomes darker and darker as more and more oxygen is absorbed, until at last the familiar black cloud is produced. The transparent material obtained still contains metallic copper, and, if it is treated with a dilute acid, a brilliant film of metallic copper is left behind. The peculiarity of copper in this state is that it is quite transparent and allows white light to pass through, and if examined under a microscope it is seen to be uniform in texture and translucent.

Other metals have been examined, such as aluminium and Dutch metal, and these do not become transparent when heated in air to any observed temperature. There has been much speculation in reference to the nature of the colours which are produced upon steel during tempering and upon copper when it is heated. These colours present an appearance of great beauty and follow in the order of the rainbow tints, and they are known to be the result of partial oxidation. The discovery of transparent copper and the probability of the existence of transparent iron would afford an adequate explanation of the formation of these beautiful iridescent films.

Though at present there is no apparent likelihood of transparent metals having any practical application, the discoveries have attracted considerable interest amongst scientific men. With regard to the thickness of the metal, Professor Turner has shown, in the case of silver, that metal one-ten-thousandth of an inch in thickness or upwards does not become transparent when heated, and assuming that the action goes on from both sides of the sheet at once, the thickness actually operated upon in Professor Turner's experiments is apparently one-four-millionths of an inch.

With regard to the photos exhibited, they represented sheets of silver placed upon glass and heated to the temperature indicated and then exposed to the same amount of light on a photographic plate, to show the proportion of light transmitted. At 150 degrees the plate was quite opaque. At 240 degrees it was practically opaque, but it was just beginning to allow the light to pass through. At 335 degrees there was appreciable transparency; at 370 degrees it was almost transparent, and at 390 degrees the transparency was quite complete. In each case the exposure to the temperature was for a few moments only. By continued exposure similar effects can be obtained at lower temperatures. The heating in all cases was effected in a muffle or air-bath. With regard to the transparency, the figures written in ink on one side of the glass slide are clearly visible on the other, which may be spoken of as a common-sense, practical test. The specimens shown were recently exhibited by Professor Turner at the Royal Society, the Royal Institution and the British Association.

Our representative had the opportunity of examining these interesting specimens after their exhibit before the Royal Society and at the Royal Institution, London, and some of them may be described as exquisitely beautiful, suggestive, in fact, of the appearance of a beautiful sunset. The professor explained that the colouring begins with orange, then goes through red and green to blue, then through orange again, and, in fact, goes through the whole range of the rainbow colours several times in the course of heating. It may possibly be that the discoveries may have a practical interest to jewelers; they may also explain the deterioration that takes place in silvered mirrors under certain circumstances, and also why gilt frames lose their briliancy.



Current Topics

THE present interest in the subject of the conservation of natural resources is a matter which should attract the attention of the engineer, of all men, but at the same time it is altogether possible that the question has more than one side.

Waste is always to be deplored, but there is such a thing as an unreasoning economy. About two generations ago it was not uncommon to find elderly people who were most anxious about the reckless manner in which firewood was being consumed, fearing that very soon there would be no more fuel, and that coming generations would be obliged to go cold because of the thriftlessness of thoughtless people. The general introduction of coal as fuel set aside these unwarranted fears, and although wood burning has become somewhat of a luxury, nevertheless we still manage to keep warm, even in the coldest weather.

To-day we are learning that some of our natural resources are reaching a point at which they will have to be husbanded, unless some substitute can be found by which they may be replaced. Such replacements, however, are already beginning to appear. If the timber-house is to be replaced by the structure of concrete we may find in this a reason for satisfaction rather than regret. The increasing cost of coal will doubtless prove the necessary incentive toward the development of methods for utilizing the heat of the sun and of other sources of energy. These are only indications of the possibilities which are before us, possibilities which the engineer is already turning into realities.

In some directions the engineer and the chemist are already making good so far as the artificial production of substances formerly found in a state of nature is concerned. Synthetic dyestuffs are already replacing the vegetable dyes of the past generation, and before the natural deposits of nitrates are altogether exhausted there is every reason to believe that the commercial fixation of atmospheric nitrogen will be satisfactorily effected.

The utilization of the lowest grades of fuel, such as the lignites and the peats, for the generation of gaseous fuel for use in the internal-combustion engine, will postpone very materially the fulfillment of the dire predictions as to the exhaustion of the coal deposits of the world, while the possibilities of coal deposits yet practically unworked, as in China, Alaska and elsewhere, remain to be considered.

A large portion of the present

wasteful consumption of fuel is connected with metallurgical operations, but with the progress of electric smelting, using current produced by hydraulic power, this cause of loss may be materially reduced. The enormous demand at the present time for iron and steel products arises very largely in connection with existing methods of building construction and railway building, and with possibilities of transformation in the materials of building and of the developments of mechanical travel and traction upon general highways, the curve of the consumption of steel may change its shape, if not its direction of curvature.

However these things may be, we should not forget that many parts of the world are as yet utterly undeveloped, in the modern technical sense of the term, that great territories still remain for exploitation by the engineer, not only for their mineral resources, but for their water power, for their agricultural possibilities under modern scientific method; in short, that they may be compelled to deliver up their riches "for the use and convenience of man."

ENGINEERS, as a class, are apt to be unimaginative. Perhaps the unimaginative engineer ought not to be called an engineer at all; as one writer has called him, he is a mere mechanic. We fear this is true. Many of our self-called engineers are little else than mechanics, high-class mechanics, it may be, highly skillful constructors of first-class machinery, but still not engineers. Let us take the men brought up in a first-class locomotive shop. There is no finer machine than the locomotive. It is a compendium of mechanism and steam plant gathered into the narrow limits of standard rail-gauge and loading-gauge that has no equal. But the ordinary pupil who learns the art of locomotive-building may rise step by step to the position of locomotive superintendent of the biggest railway in the world without having gone more deeply into engineering than a mere mechanic. He progresses along constructive lines with the very engines he builds, adding a bit here and a bit there from year to year, and modifying previous work step by step. But he never starts absolutely *de novo;* he merely muddles along more or less successfully, feeling his way, and never going far from the beaten path. Perhaps in all mechanical engineering there never has been an example of the successful imagination which stamps engineering as different from mere mechanical work, so marked as in the case of the two latest Cunard steamships. This step was so great from previous effort that it was no piece of muddling along or adding of a bit. And this gift of imagination should be cultivated. One sees the absence of it in the witness chair of a Commons committee on a bill when men who think they are engineers condemn, in abusive terms, every proposition they are unable to understand themselves. It was so in Stephenson's time. Old Geordie did at least possess the power of imagination, which, in other words, is intelligent foresight.

IN discussing the subject of the conservation of natural resources, most of what has been said relates to the necessity for less wastefulness, without including any very definite indication as to just how wastes are to be cut off. In one direction, however, there seems to have been made a very positive move, and it is most significant to note that the period of the primitive, crude and wasteful "bee-hive" coke oven is approaching its termination in the Connellsville coke district of Pennsylvania.

This interesting fact is shown in the announcement that the H. C. Frick Coke Company has discon-

tinued its plans for the construction of 1,700 new bee-hive ovens in Fayette county, involving an expenditure of about $3,000,000, the capacity of these ovens to be replaced by a large by-product coke-oven plant at Gary, Ind. This means that it is considered advantageous to haul the coking coal of the Connellsville district to Gary in order that the great steel works may have the benefit of the large volume of rich coke-oven gas, and that in this manner one of the reckless wastes hitherto incurred in coke-making in the United States is to be cut off.

The subjects of the by-product coke oven, and of the great economies effected by its use, have been discussed at various times in the pages of this magazine, and some of the fullest and most authoritative recent articles upon the question appeared in the special number devoted to the subject of gas power, published in November, 1907, showing the large value of the chemical by-products, sulphate of ammonia, etc., as well as the rich gas, available for power, heating and illumination.

It is an encouraging sign of the times that the primitive and wasteful bee-hive oven is to go, and it is to be hoped that it will soon be followed by other wasteful methods of manufacture which might well be replaced by modern systems.

JUST at present there is a good deal of discussion as to the propriety of driving cotton mills by electricity. One school advocates electricity at any price. The other school points out that, so far, all the claims made for the superiority of electrical driving are derived from comparisons of old mills driven by slow-running engines, and electrical driving with fast-running engines. It seems to be beyond dispute that economy of fuel has not, so far, been proved to have been incurred in any new mill by means of the electrical drive. Again, it is argued that if electricity is to be a success, it will not be made so by the crude exchange of a rope pulley for an electrical motor. Electricity should be called on to perform something which cannot be performed without it. In this connection the Brown Boovi system of variable-speed spindles in ring frames is referred to as an example of what can only be done by means of electricity. If by some such means a serious increase of output was brought about, there would be a powerful argument for electrical driving.

Some engineers scoff at the crude way in which electric motors are dumped down on the floor and bolted to the machines, while all the time the electrical enthusiasts are shouting abuse on belting. And they do but exchange one belt for another less suitably proportioned to do its work. Then another set of enthusiasts who abuse existing belts, do nothing but replace rope drums by motors. Now, this is not electrical driving. It resembles the first rough efforts in driving machine shops. The electrically-driven lathe now carries its own inbuilt motor, and we fancy when electrical driving has established itself in the cotton factory it will be by means of inbuilt motors, which will enable the number of spindles in a frame to be increased rather than decreased.

Perhaps the most suggestive thing is the driving of such spindle in a ring frame by its own induction motor. An expert electrician is said to have expressed the belief that this could be done. The spindles would all run at exactly the same speed, for the motors would be synchronous. And the abolition of the present two 10-inch tin rollers, which now drive the spindles, would narrow the frames so much that 50 per cent, more spindles could be put upon the same floor space. The difficulty then would be the arrangement of the creel to accommodate the necessary rovings. But, if possible, it would be a great move in favour of electrical driving.

D. W. BRUNTON

President of the American Institute of Mining Engineers

A BIOGRAPHICAL SKETCH.

THE new president of the American Institute of Mining Engineers, Mr. D. W. Brunton, was born in 1849 at Ayr, in Canada, and after an engineering education at Toronto, followed by a post-graduate course at the University of Michigan, began his practical career in Colorado as engineer to the Dakota & San Juan Mining Company in 1875; followed by engagements with the Hunt, Douglas and Stewart mill, at Georgetown, and the Clear Creek Reduction Works, Colorado. In 1878 he went to Silver Peak, first as mining engineer and later as manager, for the Silver Peak Mining Company, and in 1880 he left Nevada and went to Leadville, and, in partnership with Mr. F. H. Taylor, built the Taylor & Brunton Mill in California Gulch.

Mr. Brunton also undertook important consulting engagements, and by 1893 this department of work attracted a large part of his time, and he removed to Denver, where he opened an office as consulting engineer.

One of the most important undertakings carried on by Mr. Brunton was the construction of the Cowenhoven tunnel at Aspen, a double-track bore, 2½ miles long, driven under Smuggler Mountain, for the purpose of providing drainage, transportation and ventilation for the principal mines of the district.

The extraordinary difficulties involved in driving this tunnel through the water-saturated dolomite sand encountered in places, and the very high rate of progress maintained, sometimes reaching more than 420 feet per month whenever the heading was in solid rock, attracted much attention. A paper describing this work was awarded the Telford Medal of the Institution of Civil Engineers, and the miners engaged on the work presented Mr. Brunton with a gold medal to commemorate the care and forethought which enabled the tunnel to be constructed without a single accident.

Perceiving the defects in the old-fashioned system of establishing the value of ore by hand-sampling, Mr. Brunton invented the method of "mechanical time-sampling," and, in 1899, Messrs. Taylor & Brunton built a sampling plant at Aspen, to operate this system, this being followed by a chain of samplers extending over Colorado, Utah and Nevada, thus developing the largest business of this kind that is known in the world.

As a consulting engineer Mr. Brunton has made examinations of properties in the principal mining districts of the world, including all parts of America, from Alaska to Argentina, as well as in Europe, Asia, Africa, Australia and New Zealand; his clients, including among others the Mines, Limited, of London, The Anaconda Copper Mining Co., The Amalgamated Copper Co., New Jersey Zinc Co., Rio Tinto Mining Co., of Spain; and the Drainage Association of Cripple Creek. Among his many inventions his pocket transit is well known and widely used.

Mr. Brunton, in addition to his membership in the American Institute of Mining Engineers, is a life member of the Institution of Civil Engineers, a member of the Royal Geographical Society, the American Association for the Advancement of Science and vice-president of the Colorado Scientific Society.

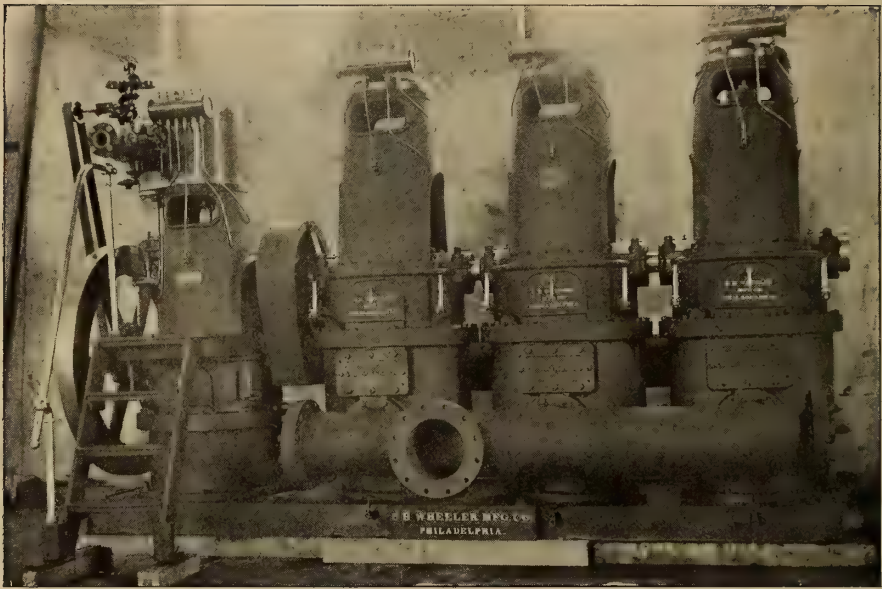
Manufacturing News

Independent Surface Condensers

THE use of the condensing engine has become almost as general on land as at sea, wherever a sufficient supply of condensing water can be obtained, and in both situations the independent condensing apparatus has found extensive application. Thus the steam turbine depends for its maximum efficiency upon a high vacuum, while at sea the use of the surface condenser insures a supply of pure water for the boilers, and in both cases the engine performance is improved in proportion to the effectiveness of the vacuum.

One of the latest improved types of surface condenser, adapted either for stationary or marine service, is that designed and built by the C. H. Wheeler Manufacturing Company, of Philadelphia, and shown in the accompanying illustration. This condenser is of the improved counter-current type, and is built with a shell of either cast iron or steel, with brass tube-heads. The water ends are of cast iron, arranged with bridges, to give the water two or more passages

COUNTER-CURRENT SURFACE CONDENSER FOR MARINE OR STATIONARY SERVICE. C. H. WHEELER MANUFACTURING COMPANY, PHILADELPHIA



MULLAN PATENT SUCTION VALVELESS TRIPLEX AIR PUMP, STEAM DRIVEN. C. H. WHEELER MANUFACTURING COMPANY, PHILADELPHIA

through the interior of the tubes, while suitable deflectors are arranged in the steam space to direct the flow of exhaust steam and insure the full operation of all parts of the cooling surface.

In building these condensers, special consideration is given to the requirements of each installation, as to the temperature of circulating water, quality and quantity of same available, and type of circulating pump that will be used. The maximum quantity of steam to be condensed, the design of air pump required and the space available for the installation are all factors in determining the design of the machine. Tubes used are of seamless-drawn brass, and are either ⅝ inch, ¾ inch or 1 inch diameter, depending upon the operating conditions.

The vacuum pump shown in the illustration is of the vertical triplex type, each pump cylinder being single-acting and of the "suction valveless type," having discharge valves only.

The pump is driven by a vertical, single-cylinder engine of heavy design, and usually operates the pump through a two-to-one reduction gearing, the engine running at 200 revolutions per minute and the pump at 100 revolutions per minute, the gearing being machine-cut and with bronze pinion. At a somewhat additional expense the engine can be direct coupled to the pump shaft, a larger engine being used, designed to run at the slow speed of the pump. The pump is brass-fitted throughout, having heavy brass liners and pistons and two bronze pump-rods to each piston, and the inverted engine type frame makes a very rigid and compact machine. Further, the "suction valveless" principle enables the pump to be operated at a high piston-speed without shock, while at the same time producing the highest possible vacuum.

These outfits are installed for a vacuum within one to two inches of the barometer for turbine practice.

For stationary installations the pumps are also built horizontal, to locate underneath the condenser, and various combinations of engine or motor-driven machines are made to suit varying conditions.

The Mosher Water-Tube Boiler

THE extending use of the water-tube boiler in marine service is one of the important developments in steam power on shipboard, and although the water-tube boiler made its early noteworthy records on fast yachts, torpedo boats and similar craft, it is now also employed in large units on many large vessels. The boilers of the Mosher Water-Tube Boiler Company, of New York, have made an admirable record for themselves, and in their various types have shown that they are adapted to all kinds of marine service and for various methods of firing. We illustrate herewith some of the forms of Mosher boiler, which enable the advantages of the design to be appreciated and its wide applicability to be seen.

The general arrangement of the Mosher boiler is seen in Fig. 1, which is the type designed for torpedo boats, torpedo-boat destroyers and scout cruisers, in which a high forced draught is used. It will be seen that all the tubes are given a slight curve, so that they aim towards a row of hand-holes in the upper portion of the steam drum, through which as many as fifty tubes may be withdrawn and replaced when necessary

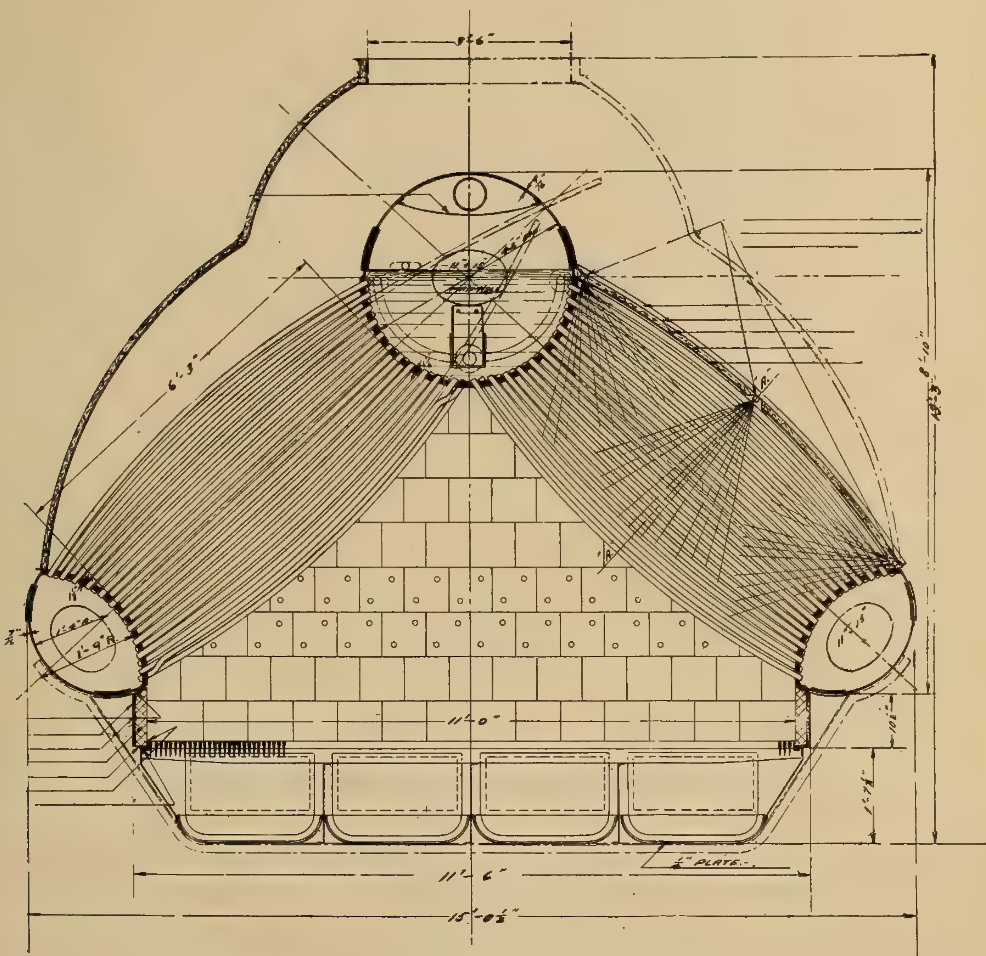


FIG. 1.—MOSHER WATER-TUBE BOILER FOR TORPEDO BOATS, DESTROYERS AND SCOUTS

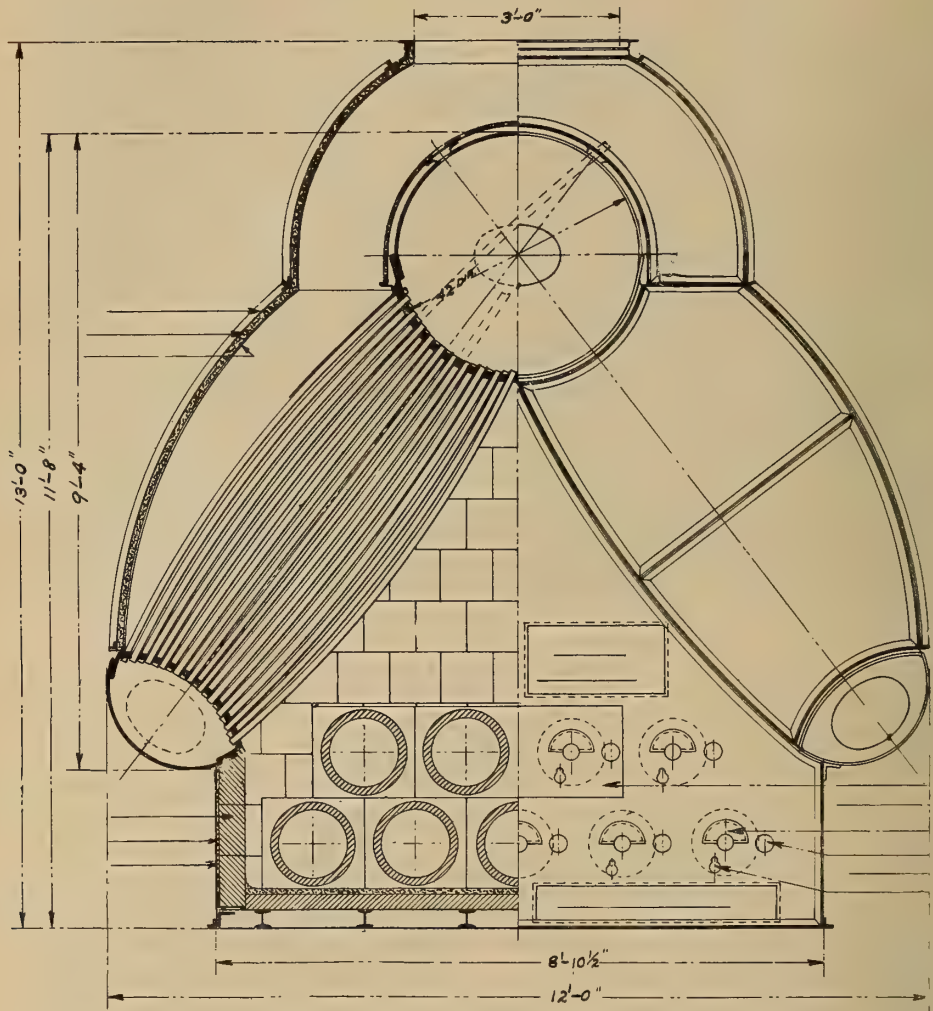


FIG. 2.—MOSHER PATENT WATER-TUBE BOILERS FOR HIGH-SPEED YACHTS, ARRANGED FOR OIL-FIRING

by removing a single hand-hole cover in the upper portion of the steam drum. The illustration shows only a cross-section of the boiler; but in the longitudinal arrangement the tubes next to the furnace are spaced their own diameter apart, each tube in the first row being bent between the two adjoining tubes of the next row, thus providing a tubular wall, which extends from the fire-door end for three-quarters of the length of the furnace. For the remaining fourth of the length of the furnace the tubes are not bent between the adjoining tubes of the next row, thereby leaving an opening for the passage of the gases of combustion to pass from the furnace among the tubes into the stack at the opposite end of the boiler.

The sides and ends of the furnace are lined with fire-brick, which is secured to a steel casing. At the ends of the furnace is a second steel casing, forming an air space connecting with the ash pan. The fire-brick is provided with small circular openings, permitting the heated air to pass from the ash pan through the

air space into the furnace above the fuel.

At *B, B, B* are shown perforated pipes, extending the entire length of the boiler, and provided with a number of rows of holes opposite the space between the tubes, permitting jets of steam to be blown among them. Thus, any soot which may have accumulated on the tubes may be blown off simply by opening a steam valve connecting these pipes with the boiler.

The feed-water is delivered through a connection on the lower part of the front head of the steam drum, this connection being provided with internal feed-distributing pipes extending the whole length of the boiler opposite the two outer rows of tubes. These pipes are provided with openings opposite each of these tubes, causing jets of feed-water to be projected down through the outer tubes, and, as these feed pipes are below the water level of the boiler, they act as siphons, causing large volumes of water to be sucked down through these tubes, thereby forming an economizer or feed-water heater of the two outer rows of tubes. This arrangement also forms a system of

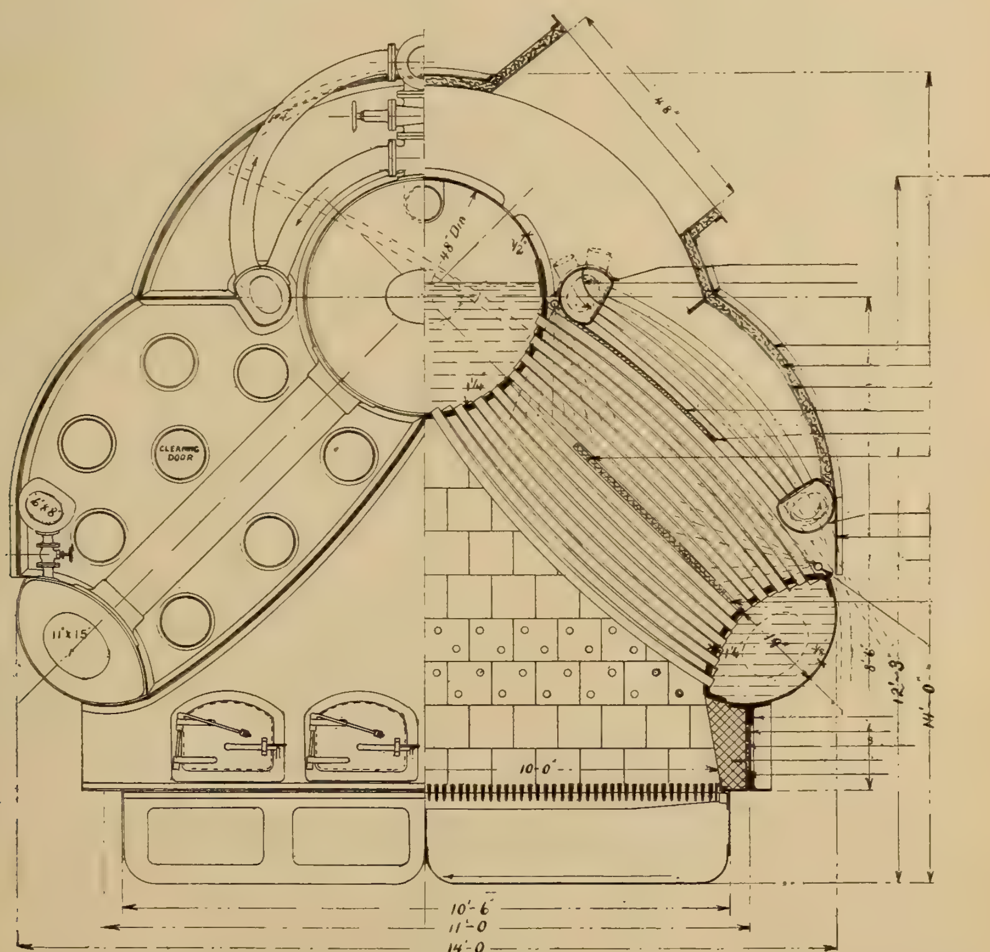


FIG. 3.—MOSHER PATENT WATER-TUBE BOILER AND SUPERHEATER FOR BATTLESHIPS, COLLIERS AND CRUISERS

forced circulation, thus causing the boiler to be thoroughly reliable even when forced to a rate of evaporation of more than 18 pounds of water per square foot of heating surface, an amount nearly double that recorded for any other boiler.

In Fig. 2 this type of boiler is shown as arranged for burning oil fuel, under the Schutte & Koerting system, as adopted by the British Admiralty. This includes the use of fire-clay cylinders in connection with the oil burners and proper dampers for the control of the air supply.

Boilers thus arranged were furnished for the steam yacht *Arrow,* which made a speed of more than 45 miles per hour, entitling her to be called the fastest vessel in the world. This boat is only 130 feet long and 12½ feet beam, and yet, on account of their high efficiency, compactness and lightness, it was found practicable to install 4,000 horse-power Mosher boilers.

Fig. 3 shows the Mosher boiler as adapted for large vessels, such as battleships, cruisers, colliers, transports, etc. This boiler is provided with a superheater, so arranged that it may be flooded and made a part of the boiler, under which conditions saturated steam will be furnished. An arrangement of fire tile baffles causes the gases of combustion to pass in contact with all the boiler tubes before they reach the superheater on the way to the stack.

For removing and replacing the tubes in boilers of this type a row of hand-holes are provided in the upper portion of the steam drum; by removing the hand-hole covers from these openings any tube may be passed up into the space between the steam drum and casing sufficient to bring the lower ends free from the tube sheets, when the tube may be drawn back into the steam drum and taken out through the manhole.

Further information may be obtained from the Mosher Water-Tube Boiler Company, No. 30 Church street, New York City.

Reinforced Concrete Floors

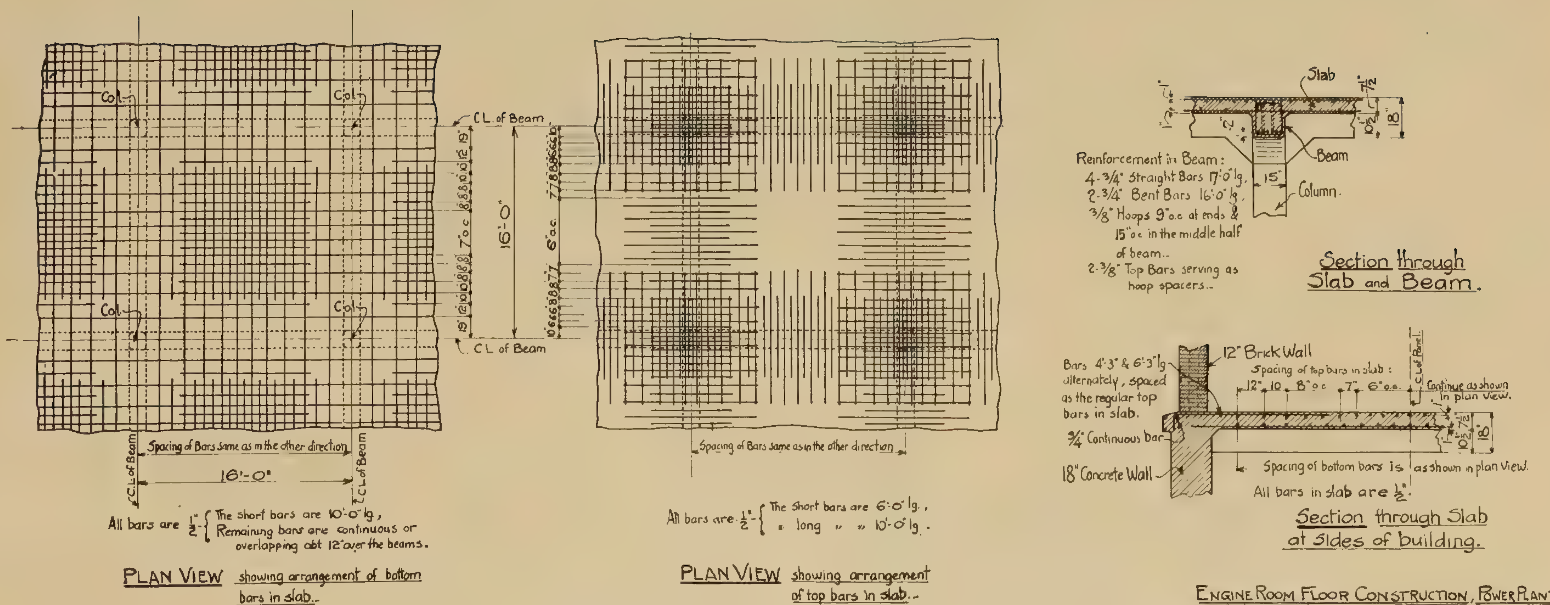
WHEN reinforced concrete construction was first introduced it was assumed that the method was so simple and elementary that almost anyone could design and build a safe and satisfactory structure of this sort. It soon appeared, however, that engineering ability was required to secure the full advantages of the united action of concrete and steel, and the result has been that several systems have been developed in which correct engineering principles have been applied to great advantage. Among these may be mentioned the system of concrete-steel floor construction invented by Mr. Leibu Hermann, C.E., and patented by him, and included in a number of important recent structures.

The Hermann system of concrete-steel floor construction is of the panel type, consisting of a flat slab, supported by columns and beams, so that the ceiling is divided by the beams into square or rectangular panels. The slab is composed of concrete, reinforced by two independent layers of bars placed at the top and at the bottom thereof. The reinforcing bars in the bottom layer run in two directions parallel to the beams of the panel, and the bars in the top layer are preferably wired into units beforehand, and these units dropped into place immediately after the concrete is cast. The floor panels are thus reinforced in two directions, giving a high efficiency of material and a corresponding economy in construction.

In detail the advantages and features of the Hermann system are shown by the following facts:

The resisting capacity of the concrete in the slab (if the panel is square or nearly square) in the Hermann system is about three times the resisting capacity of the concrete in the regular slab reinforced in one direction only.

For the same span and load the thickness of the slab (if the panel is square or nearly square) in the Her-



ENGINE ROOM FLOOR CONSTRUCTION, POWER PLANT of the CELLULOID Co., Newark, N.J.

John Clark Udall .... Contractor,
Ransome & Smith Co. ..... Consulting Engineers.
Leibu Hermann, C.E. ...... Designing Engr. & Supt.

Built Jan 1908

GENERAL NOTES:
Size of Floor: 97'-6" x 96'-6".
Floor is figured to safely support at any point a concentrated load of 10 Tons, covering an area of 3 ft sq.
Reinforcement used is the Ransome Twisted Bar.
Concrete mixture 1:2:4.

Scales { 3/16" for Plan Views, 3/8" " Sections.

SYSTEM PATENTED Aug. 1907, Patent # 862911
Leibu Hermann, C.E., Patentee
Room 1012, 11 B'way, N.Y.

mann system is a little more than one-half the thickness of the regular flat slab reinforced in one direction.

The belt course or outside walls (which contain sufficient material required by other considerations of construction) in the Hermann system carry along all the sides of the building a large amount of floor load, while in the regular type of construction (ribbed floor or flat slab reinforced in one way only) they carry a large amount of floor load along two sides of the building only.

In the regular type of ribbed construction, in order to avoid altering the forms, the roof (which has to carry, say, 40 pounds per square foot superimposed load), contains about as much concrete as the floor (which has to carry, say, 250 pounds per square foot superimposed load); in the Hermann system, on the other hand (most of the concrete being in the slab), the slab thickness can be proportioned according to the load, thus using only as much concrete as is necessary.

A large saving in amount of reinforcement is obtained by using, in both top and bottom layers of the slab, alternately long and short bars, and also by spacing the bars further apart near the beams.

The compressive stresses in the slab produced by the deflection of the beams reduce the tensile stresses in the bottom of the slab.

The cost of labour, handling and placing steel is low, because there are no bent bars in the slab; and the cost of wiring the bars occasionally where they cross each other is insignificant (one man can easily do 240 wirings in one hour).

The placing of the concrete in the slab is facilitated and its compacting is done better because there are no bent bars in the slab and because the top reinforcement is placed after the concrete is cast.

The spacing of the bottom bars in the slab is easily done by using notched wooden strips, and the bars are kept in position by wiring them occasionally where they cross and by placing under these wired points small grooved concrete blocks.

The spaces between the top bars in the slab are kept as designed by wiring the bars in advance into units. The units are quickly placed and pressed into the concrete immediately after the concrete is cast; they are held at the proper elevation by the reinforcement in the beams.

The top bars assist in distributing in the slab the compressive stresses produced by the deflection of the beams.

The top reinforcement over the columns and over the beams prevents the formation of cracks in the slab around the columns and at the beams; these cracks would otherwise occur on account of the negative bending moment.

The reinforcement in two directions is advantageous for concentrated superimposed loads; it also offers resistance to shrinkage cracks and to cracks caused by the variation of temperature.

There is a saving of at least 30 per cent. in cost of forms in the Hermann system over the regular type of ribbed construction.

The under side of the floor, whitewashed only or plastered, forms a ceiling neat and ornamental from the architectural point of view.

In the Hermann system, instead of reinforced concrete beams, structural steel beams (supported by metal columns) may be used, and the concrete slabs may be cast on several floors simultaneously.

The details of the Hermann system will be fully understood by reference to the drawing on page vii., which shows plans and sections and explanatory notes.

Full information concerning the Hermann system of concrete-steel floor construction may be obtained by communicating with the inventor, Leibu Hermann, C.E., specialist in concrete-steel construction, No. 11 Broadway, New York.

Machine Tool Controller

THE self-contained drum type machine tool controller here illustrated is a recent addition to the line of electric controlling devices designed for use with motor-operated machine tools.

It possesses the advantage of combining in one compact piece of apparatus the speed regulating mechanism and the resistance instead of constructing these separately and requiring connections between the two to be made after the apparatus is installed.

FIG. 1
Front view (cover removed), showing armature resistance units mounted in lower half of controller.

Fig. 1 is a front view of this new type of controller, and shows the removable resistance units mounted in the lower half of the controller with insulated wires running from each unit to the metal "fingers" in the upper part of the device. These units constitute the armature resistance, and are employed for starting duty only.

Fig. 2 is a rear view of the same drum, and shows another type of resistance unit—also removable—mounted on the back of the controller. The four units shown in this view constitute the field regulating resistance, and are divided into twenty steps, providing a range of speed variation of 2 to 1 or 3 to 1.

FIG. 2
Rear view (back plate removed), showing shunt field resistance units mounted on back of controller.

These controllers are made for both reversible and non-reversible motors ranging from 1 to 7½ H. P., and are designed for use on either 110 or 220-volt, direct-current circuits. They are made by the Cutler-Hammer Manufacturing Company, of Milwaukee.

The National Commercial Gas Association will hold their next annual convention at Chicago, December 8, 9 and 10, in the First Regiment Armory, Michigan avenue and Sixteenth street. Coincident with this convention the Annual Exhibition of Gas Appliances will be held. A series of interesting papers will be read; among those of especial interest might be mentioned "Industrial Fuel Gas and Special Appliances," by S. Tully Wilson, Denver, Col.; "The Consumer," by C. Willing Hare, Philadelphia, and "Pushing of Gas and Electricity Under One Control."

The Old and the New in Quarrying

LAST year at Carrara, Italy, what is said to have been the biggest blast on record was fired, and at the time it was made a prominent item of news. The purpose of the blast was to knock away the side of a mountain of purest marble, the material of the classic statues of antiquity. The work of preparation had gone on for months. Galleries were driven into the rock and the explosion was distributed with a view to producing a wide area of rupture all at once. Eight tons of high explosives were thus placed and the blast was expected to dislodge more than half a million tons of rock and send it tumbling all at once down into the valley, there to be cut up for the use of the sculptor and the architect.

The blast was fired successfully according to programme, but the result of it is understood to have been more or less of a disappointment. The accounts of it in the papers of the day must certainly have come as a surprise to those familiar with the methods and facilities of the modern quarry, for in no industry, perhaps, has there been a more complete and a more profitable transformation of practice than in the getting out of rock from its bed, while this "titanic" blast, as they called it, was typical entirely of the old, wasteful, haphazard way of working, and while a thing to be wondered at, it was also a thing to be in these days more or less ashamed of.

When explosives first came to be tried for quarrying purposes we can well suppose that a hole or holes may have been drilled without much planning as to their location, that charges of powder were then exploded in them, portions of rock of all shapes and sizes being thrown out, and that then selections were made from these of such pieces as might possibly be hewed into usable shape, while most of the material went to the dump as unavailable for any purpose. Such working as that must have had the charm of uncertainty about equal to that which the fisherman knows; but it was not business.

Modern quarrying is real business, as precise in its methods and its results, as calculable and reliable as those of almost any other line. The material wanted is cut very closely to dimensions as it lies, with the least possible waste at the beginning, with practically no uncertainty as to the value of the block when it is lifted out, and with a minimum of labor required for the final dressing of it.

For the modern system of quarrying, the channeler is the typical and most effective piece of apparatus. It is the skilled and precise worker among machines of the class which does what we might be tempted to call rough work. What it has to do is laid out with care and it cuts to the line. In the separating of the blocks of stone from the mass it is the worker distinguished by the small, rather than the large, bulk of resulting chips or debris.

This habitual neatness of working has won for the channeler another line of employment in which the material to be cut away is of little value and requires no care as to shape or size, but where the condition of the walls of rock which remain is the desideratum. For this reason it has found employment in the cutting of canals in the solid rock and elsewhere. The channeler, too, is thus, in a way, responsible for the various tunneling machines with which inventors are now busy, although none of them is as yet beyond the experimental stage. If canals or roadways may be cut in the solid rock with straight, smooth sides which require no correcting, why may not tunnels also have true, smooth sides.

The channeler has been driven by steam or air heretofore, but now that it has the electric-air drive it is not only independent of boiler or compressor, but utilizing the electric current it shows the same remarkable saving of power and liveliness of action as the electric-air drill.

Hoisting Efficiencies

THE ordinary block and tackle is a device which has its advantages, both as to simplicity and wide applicability, but it has always operated under the disadvantage of lacking in capacity to sustain the load. So long as the operator pulls on the rope, or holds it fast, so long will the load be sustained, but the moment the rope is released the load drops. Various plans have been devised to overcome this objection, and when a winch is added to the block and tackle, some form of pawl and ratchet can easily be employed to hold the mechanism from reversing. This, however, involves the use of some fixed point of attachment, and takes the apparatus out of the field of portable hoists.

When the Weston differential block was first placed on the market one of the strong points which gave it claim for general use was the rather surprising fact that it sustained the load at any point, so that there was no danger of accident from dropping of the weight, and no dependence upon any fixed attachment other than that from which the whole simple and portable apparatus hung. To many people, this feature of sustaining the load seemed almost inexplicable, and, indeed, certain eminent technical writers thought it advisable to include in their text books a mathematical demonstration to show just why this simple hoist behaved as it did. As a matter of fact, the reason is very simple. The actual frictional resistance of the apparatus is a little more than one-half of the total power required to lift any load by its use. Thus, if such a hoist had an efficiency of 40 per cent. the remaining 60 per cent. was represented by the friction of the machine, and the weight itself was incapable of overcoming such a resistance.

When a hoist is used for short periods of time only, such a low efficiency is a secondary matter, and questions of simplicity, first cost, etc., are naturally given more consideration. When, however, as is often the case, the hoist is required to have a high degree of efficiency it is evident that some other method than that of continual frictional resistance must be employed.

These considerations have been taken into account in the design of such a hoist as the well-known Triplex block, a machine which contains the self-sustaining feature, and the mechanism of which is so arranged that the resistance which sustains the load is not opposed to the effort of the operator during the period of hoisting. In other words, the brake is taken off the wheels and the bit put in the horse's mouth.

By thus relieving the apparatus of the burden of a constant amount of internal friction for the purpose of holding the load, it becomes possible to limit the actual frictional resistances to those inherent in the hoisting mechanism. These resistances are those of the system of gearing by means of which the speed ratio is effected, and those of the chains and sheaves. By the employment of a spur-gear train and the separation of the hoisting chain from the hand chain it has been found practicable to keep the actual operative losses in the hoist as low as about 20 per cent., leaving 80 per cent. of the effort of the operator free to act in raising the load. The moment the hand chain is relieved of pull, however, the sustaining resistance comes into action, so that the load is held at any point, just as in the case of the original differential block.

By thus separating the hoisting and the sustaining resistances, it has become possible to produce chain blocks of higher efficiency than heretofore, with the result that such blocks are made of larger capacity and far wider fields of usefulness than could otherwise have been possible.

This separation of the hoisting and sustaining resistances was first made in the Triplex block, and is now fully accepted as a fundamental principle of design.

The Coaling of Steamships

A STEAMSHIP, among other things, is a great power station. It is also many other things—sometimes a floating hotel, sometimes a navigable fortress—but whatever it may be in such respects it has to contain a power plant, including engines, boilers and auxiliary machinery; and at the present time the largest power units in existence are found on board the great transatlantic liners and on the powerful battleships of the navies of the world.

So far as the handling of the fuel for these great floating power houses is concerned, it is necessarily an altogether different operation from that involved in the supply of coal for a land station. A ship, in order that its work may be effected at maximum efficiency, must be at sea for the greater part of its life. For a warship the so-called "steaming radius" is a critical element in its efficiency, and this element is dependent largely upon its fuel capacity and rate of fuel consumption. As a matter of fact, the fuel capacity is the controlling feature, and if, by reason of improved engine design, the fuel consumption is reduced, no reduction is made in the coal capacity, but the gain is used to extend the steaming radius.

This means that every possible facility must be provided at the terminal ports for the handling of merchandise, passengers, stores and fuel. The old methods of employing manual labour are thus being replaced by mechanical appliances, not only for the purpose of securing the reduction in cost which is thus effected, but also with the object of reducing the time during which the vessel is idle.

In the case of warships the question of coaling is often of critical importance. Thus, during the voyage of the Russian fleet from Libau to Tshushima much difficulty was experienced in coaling in neutral ports within the time limits imposed by international comity, and the fuel question was one of life or death, in so far as the fighting value of the fleet was concerned. Again, the opportunities for coaling are often limited to periods when the space at the coaling station is available, and the possibilities of handling hundreds of tons of coal within a few hours govern the whole situation.

Modern coaling stations, therefore, involve the design and operation of special machinery, and demand the exercise of skilled engineering ability combined with practical experience in this peculiar department of work. The stationary power plant may receive coal at any time; its storage bins may be planned with regard to demands rather than with respect to space limitations, and the problem is far simpler than that of the floating power house on shipboard. Coaling wharves should be planned with a maximum of available space for vessels and equipped with handling machinery capable of delivering the maximum quantity with a minimum of time expenditure, while with these critical requirements must be included reliability in the extreme, a reliability which shall know no failure or interruption in the midst of an operation in which delay or obstruction may be fatal.

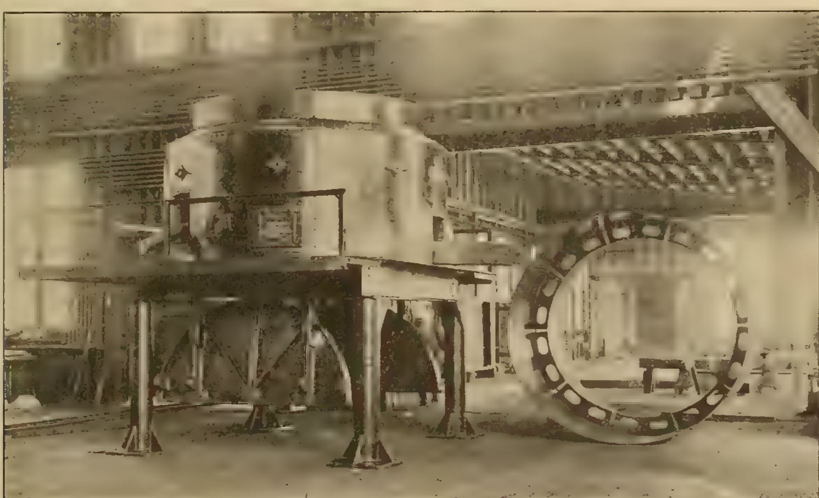
That these stringent requirements have been successfully met is seen in the remarkable coaling records which have been made as a result of the competition which has been developed at various points, especially in connection with the coaling of warships. At the present time the record, made by a modern plant at Puget Sound, Washington, in connection with the coaling of the United States battleship *Virginia*, is the loading of 1,667 tons of coal in four hours, with a maximum of 555·9 tons in one hour, an example of what can be accomplished by the use of proper appliances designed for the work and intelligently handled, with the incentive of previous performances as standards.

Manufacturing News

A Notable Cupola Installation

BELOW is given an illustration of two No. 12 cupolas recently furnished the Standard Cast Iron Pipe & Foundry Company, Bristol, Pa., by the Whiting Foundry Equipment Company, Harvey, Ill. The description is of especial interest, as this is the largest standard foundry cupola offered by any manufacturer in this country. The design follows the same principles as the standard Whiting cupola. Several new features, however, have been added.

The shell is 108 inches in diameter and wind box 130 inches diameter, and with a 10½-inch lining; has a capacity of 27 to 30 tons per hour. It is fitted with two rows of tuyeres, eight in each row.



TWO NO. 12 CUPOLAS. WHITING FOUNDRY EQUIPMENT CO., HARVEY, ILL. (CHICAGO SUBURB.)

The bottom plate presents some

new features in cupola construction. On account of extreme loads carried, bottom plate and framing is entirely of structural steel. It consists of a heavy steel plate securely riveted to shell and wind-box sheets and bolted, in turn, to the bottom frame, which consists of heavy steel beams securely riveted together. Hinge plates for bottom doors are steel castings riveted to structural steel frame.

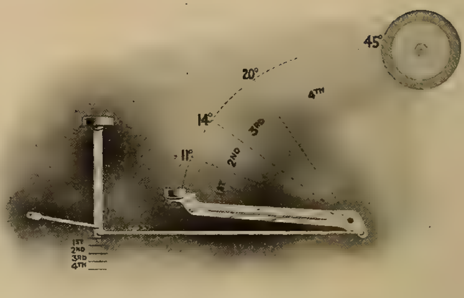
For the usual curved columns straight cast-iron columns of circular hollow section are substituted. Each of these columns is provided with a large flange, making the use of a separate base plate unnecessary.

The safety tuyere on this cupola is provided with a spout projecting through shell of wind box. This spout is lined, and is provided with the usual safety slide. It is located so that it can be always under the eye of the cupola tender.

Owing to the size and height required for bottom doors, the standard cupola is provided with an operator's platform built up of structural material and checkered plate floor and substantial hand rails.

An Improved Type-Bar Action

IT has long been realized that, for many pieces of mechanism, the effect of rapid impact is more desirable than an apparently equivalent pressure. This is especially true of the action of writing machines of the type-bar class, and some ingenious devices have been evolved to meet the conditions which obtain in the modern typewriter. One of these mechanial movements which has been found most effective for its purpose is found in the acelerating type-bar action of the Royal typewriter, as shown in the accompanying illustration. The Royal typewriter is a machine of the visible-writing variety, in which the type bars are arranged in a semi-cylindrical manner beneath the roller, striking from below upwards, and the action which the inventor, Mr. Edward B. Hess, has devised for converting a uniform depression of the key into a rapidly accelerated movement to the type-bar is very effective in practice.



THE ROYAL ACCELERATING TYPE-BAR ACTION

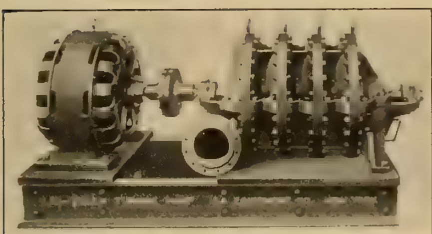
The type-bar itself forms a sort of bell-crank lever, to the short end of which is attached a flexing connection, forming a toggle with links of unequal length, the push pin upon which the key is carried pressing downward upon the connection of the toggle links, thus exerting a tension upon the links and a corresponding pull upon the short end of the type-bar, causing the long end of the bar to rise and strike the ribbon and produce an impression upon the paper. When the depression of the key first begins the movement of the type-bar is relatively slow and the resistance correspondingly small, while with the continued depression of the key the velocity of the type-bar is increased, being accelerated until the impact upon the roller is effected. The rate of acceleration is clearly shown in the illustration, the depression of the push pin being divided into four equal parts, and the corresponding angular movements of the type-bar being 11, 14, 20 and 45 degrees. This acceleration affords a more refined performance of the machine, and especially enhances its value for speed and for manifolding.

From constructive reasons this movement has manifest advantages, since both links of the toggle are subjected to tensile stresses only, permitting the use of parts at the same time strong and light, giving a minimum of inertia effect.

The Lea-Degen High-Duty Turbine Pump

THE high-efficiency turbine pump has been so well exploited within the last few years that it needs but little introduction. The prevailing types, however, have many drawbacks, and with the view of overcoming these the Lea Equipment Company has devoted nearly four years to the development and testing of a line which more nearly fills commercial and theoretical conditions than anything heretofore attempted.

The complete line of pumps are made of separable units that are designed for heads from 7 to 1,000 feet or higher, and their capacities ranging from 75 gallons to 30,000 gallons per minute.



FOUR-STAGE PUMP DIRECT CONNECTED TO MOTOR

Being built in separable units and parted both horizontally and vertically, it is possible to quickly assemble any number of stages required, and by the use of a small number of standard parts an endless variety of combinations can be produced. After these sections are bolted together the top can be easily removed, allowing inspection of packing and wheels.

Packing, which has always been a source of trouble, has been entirely removed in the Lea-Degen pump. It consists of right-angle cup-leathers, held in place by springs in such a manner that they are tight under all conditions; allow the shaft to oscillate throughout any distance necessary, and are quickly renewable. It is not affected in any manner whatever by wear of shaft or sleeve, as is always the case with hemp or other packing placed in the stuffing box.

Both suction and discharge water connections are placed below the centre line of the pump, allowing removal of top without breaking water connections, and at the same time they are of such shape as to give practically no obstruction to the easy flow of the water.

The shafts are made straight throughout their length, with no shoulders except at the bearings. The wheels are held in place by taper bronze sleeves, allowing the easy removal of impellers, even should parts become rusted. These sleeves cover the shaft throughout its exposed parts, and also form parts of automatic packing.

By the Lea-Degen patented diffusing nozzle deflectors it is possible to get extremely high efficiency throughout a large range of service, and, as there are no loose parts to become loosened, the pump will remain indefinitely in working condition and retain its efficiency.

Bearings are all of a self-oiled type; have no connection whatever with the suction or discharge line, and it is impossible for water to leak into them.

Bases are made from cast-iron distance pieces, bolted to steel channel beams. By this plan it is possible to quickly deliver bases of any length or sizes required.

In general, it may be said that by this method of unit construction it is possible to quickly assemble a pump for almost any general requirements, one that is accessible, not liable to get out of order, and with an efficiency higher than anything now on the market. The present line comprises sizes of from 3 inches to 24 inches suction and discharge, and other sizes larger than this will be built to order.

Full reports of tests made by Professor Denton can be had upon application to the Lea Equipment Company, 136 Liberty street, New York.

Dustless Roads

TO illustrate how some students of highway problems regard the question of incorporating a binding material with the earth or metal of which a road is to be surfaced, the following interview with Col. Crompton in the London *Daily Mail* is quoted from the *Surveyor:*

"The dust problem on English roads promises soon to be a problem of the past. It is being solved by developments of road tarring. Two years ago there were 30 miles of tarred roads in England; last year there were 200 miles; there are now 1,500 miles; and in two years you may expect 20,000 miles. On these roads the dust problem is absolutely killed.

"Up till recently what tarred roads we had were nearly all in short lengths. Now long stretches have been completed, such as from Coventry to London and from London to Herne Bay. In many counties, notably Hertfordshire, Middlesex and Kent, the advance has been very rapid.* * * *

"To-day England leads the world in road improvement. France comes next. Five years ago the routes nationales in France were, as a whole, superior to our roads as a whole, although not equal to our best. To-day we are enormously ahead even of France, and the work done in other countries is comparatively small.

"Tar fresh from the gasworks is totally unsuitable for using on the roads. It contains a proportion of soluble matter which washes out and which, if it runs into streams, may kill fish and do other damage. The ordinary tar splashes and injures dresses, etc. These facts have caused considerable natural prejudice against tar preparations among many landowners and country residents. Methods had to be found of removing the soluble matter without going to the other extreme and making the coating brittle. There are now various ways of doing this.

"The Roads Improvement Association's experiments showed that roads can be made dustless by applying 1 gallon of tar to every 4 superficial yards, costing about $200 a mile for an average road. We found that satisfactory results could only be had by giving much heavier dressings than was formerly considered necessary.

"This tar dressing so adds to the wear-resisting qualities of the highway that, so far as can be now seen, it will more than repay its cost by the saving it effects in road maintenance. But it is not possible to speak finally on this point until the tarred roads have been laid down for a longer period."

Interesting Installation of a Fairbanks-Morse Gasoline Engine

The new Scherzer bascule span at Cleveland, Ohio, was built this year by the New York, Chicago & St. Louis Railway across the channel of the Cuyahoga River, at Cleveland, Ohio.

The viaduct has a total length of nearly 3,000 feet and is about 60 feet high, the rolling lift span across the river channel being 70 feet above the water.

This bascule span is a double-track, single-leaf-throughout bridge, 160 feet long, centre to centre of bearings, and 29 feet 6 inches wide, centre to centre of trusses. The clear channel for navigation allowed by the new bridge is 120 feet, measured at right angles to the channel, the bridge crossing the river at an angle of about 62 degrees.

The bridge is operated by two direct-current electric motors of 50 horse-power each. There is also a 9 horse-power Fairbanks-Morse gasoline engine auxiliary, to operate the bridge should there be any trouble from defective current or electrical equipment. This 9 horse-power engine will lift the bridge in twelve minutes, doing the work of two 50 horse-power electric motors in case of a breakdown.

News Items

The Nernst Lamp Company has received a contract from the Rosenbaum Company, proprietors of one of the largest department stores in Pittsburg, for an installation of three-glower Westinghouse-Nernst lamps, replacing the six-glower Nernst lamps which have been in use for the past four years.

The contract was a result of comparative tests made in different departments of the store with Westinghouse-Nernst and Tungsten units.

Mr. H. P. James, formerly electrical engineer of the Bryant Electric Company, now occupies the position of sales manager for the new line of push-button specialties recently placed on the market by the Cutler-Hammer Manufacturing Company, of Milwaukee. Mr. James is a graduate of the Massachusetts Institute of Technology, where he received degrees in both electrical and mechanical engineering. Previous to his connection with the Bryant Electric Company he was electrical inspector and engineer for the Associated Factory Mutual Fire Insurance Companies. In his present position with the Cutler-Hammer Manufacturing Company he will have opportunity to turn to practical account the result of his past experience in the inspection, testing and manufacture of electric lighting supplies.

Hugh A. Brown has resigned from the Crocker-Wheeler Company, manufacturers and electrical engineers, to whose Chicago office he has been attached for several years. He now takes up the work of sales manager for the Rockaway Coaster Company, of Cincinnati, in which he has a substantial interest.

The G. M. McKelvy Company, of Youngstown, Ohio, have placed an order with the Nernst Lamp Company for the new Westinghouse-Nernst lamps for the entire lighting of their new four-story store building, now practically ready for occupation.

The installation will consist of thirty-six three-glower lamps for the first floor, sixty-nine two-glower lamps for the second and third floors, and seventy-five 132-watt lamps for the basement and fourth floor.

This is the largest department store in Youngstown. The building now occupied by the McKelvy Company has been lighted by the old-style Nernst lamps for several years.

One of the most important orders recently booked in the electrical field is that for about 2,500 horse-power of induction motors for the Clark Thread Company, in Newark, N. J. The order itself is of considerable size; but its chief importance is its being the beginning of the electrification of these mills, probably the most extensive cotton mill in the United States. The mill has been driven by several steam engines, and this purchase of induction motors is the first step in electric drive. The order was awarded to the Crocker-Wheeler Company, of Ampere, N. J., after a thorough investigation extending over a period of ten months. It was thus awarded because of the thorough confidence on the part of the Clark Thread Company that the Crocker-Wheeler engineers knew how to solve the intricate electrical problems met with in textile work. The high efficiency, high power factor, economy of operation and excellence of design and workmanship embodied in Crocker-Wheeler machinery were strong points; but the fact which finally determined the mill to give the order to the Crocker-Wheeler Company was the excellent showing made by the Crocker-Wheeler engineers in the previous equipment of a number of large cotton mills in the United States and Canada. The motors are 5,500-volt, 60-cycle, three-phase machines, and the present order aggregates about 2,500 horse-power, the motors ranging from 25 to 150 horse-power each.

Panama Canal Contract

ENGINEERS through the South and West are very much interested in the Panama Canal, and watch its progress closely. The Lidgerwood Manufacturing Company have recently been awarded the contract to furnish the cableways for erecting and constructing the Gatun Locks. These cableways have a clear span of 800 feet, and are self-propelling. The Lidgerwood Company were awarded the contract for $309,000—the highest of all the bids entered. This provoked protests from the lower bidders, and the Secretary of War ordered an investigation. In the investigation Col. Goethals, his assistants, and a number of other experts gave testimony to the superior construction and efficiency of Lidgerwood machinery, and explained fully why the government should pay much more for apparently the same plants. In other words, they demonstrated that, while the Lidgerwood bid was the highest in dollars, it was the lowest when capacity and quality were considered.

THE STANDARD GAUGE MANUFACTURING COMPANY, which has been actively engaged in the manufacture of indicating and recording gauges at Syracuse, N. Y., has removed its plant and main office to Foxboro, Mass. Through this change the manufacturing capacity will be greatly increased, since the two main buildings alone have available floor space of one hundred thousand square feet, besides separate buildings for the foundry, blacksmith shop, carpenter shop and power plant. The growth of the Standard Gauge Manufacturing Company has been steady since its inception in 1899, so that this epoch in its development will not surprise its many patrons, who appreciate the solid foundation of quality upon which the reputation of standard gauges rests. The sales office addresses will be, as heretofore: New York, 1770 Hudson Terminal, Fulton building; and Chicago, 752 Monadnock building.

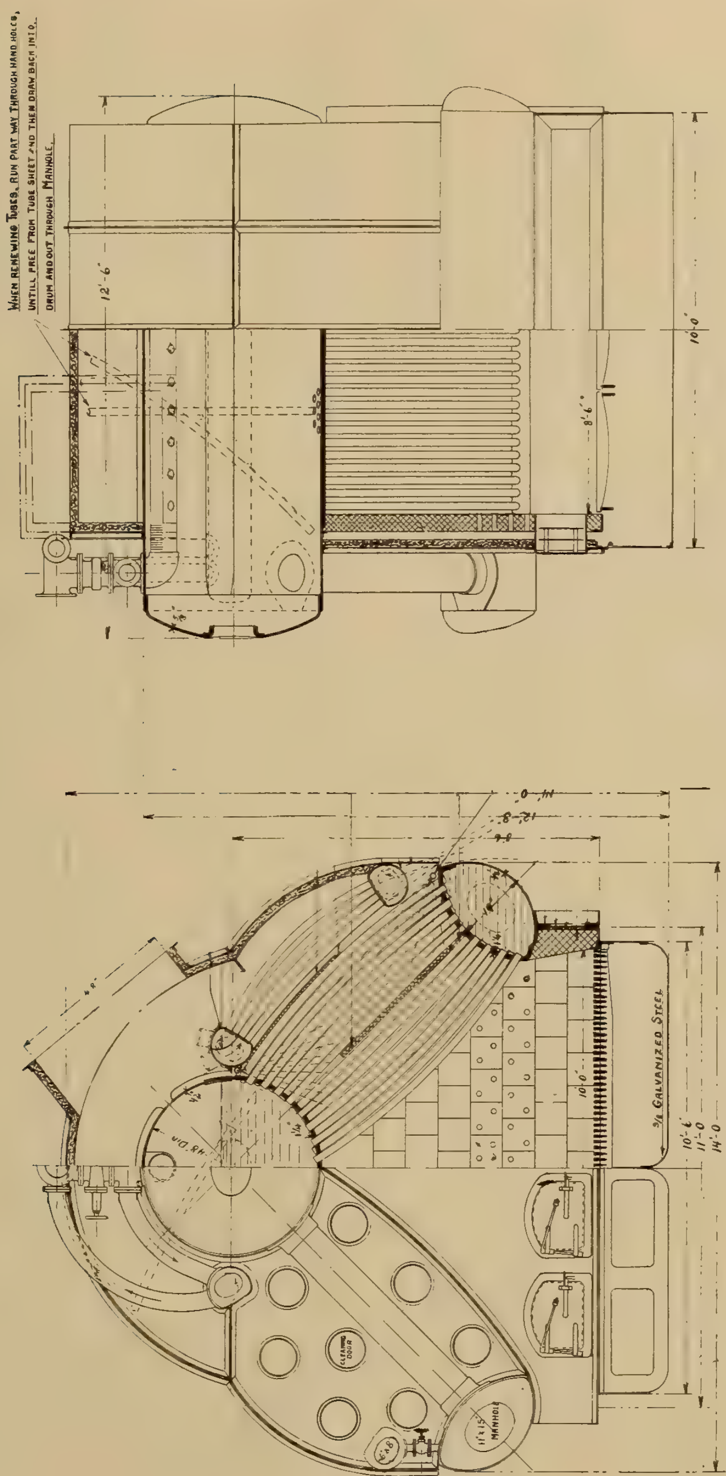
The Mosher Marine Boiler

AN important matter in connection with the use of water-tube boilers for marine and naval purposes is the provision of abundant facilities for the removal of tubes without disturbing the general setting of the boiler.

As is well known, the Mosher boiler is made with curved tubes, the curvature being so arranged that they aim toward a row of hand holes in the upper portion of the steam drum. This permits as many as fifty tubes to be withdrawn and replaced by the removal of a single hand hole.

In order still further to facilitate the renewal of tubes without disturbing any other part of the boiler, the proportions of the parts are so arranged that no removal of any part of the casing is necessary for the removal of a tube. As will be seen by an examination of the illustration on the opposite page, the operation of the removal of a tube is effected by taking off the hand-hole cover and passing the tube up as far as necessary into the space between the steam drum and the casing, this bringing the lower end of the tube entirely within the steam drum and free of the tube sheet, after which the tube may be passed down and forward into the steam drum and taken out through the front manhole. This operation is clearly shown, both in the front and side views of the Mosher boiler, the front view showing how the tube clears the tube-sheet of the steam drum when the upper portion is drawn up into the casing, while the side view shows also how the tube is brought into the drum for removal through the manhole.

This important feature of the Mosher boiler will appeal especially to marine engineers who understand the necessity for ready command over the tubes at all times, and the simplicity of the method for the renewal of tubes thus provided constitutes a distinct advantage for this type of water-tube boiler.



MOSHER-MARINE WATER-TUBE BOILER, SHOWING METHOD OF REMOVING TUBES THROUGH DRUM

THE LATEST CATALOGUES

Conveying Machinery

THE JEFFREY MANUFACTURING COMPANY'S folder No. 67C and Booklet No. 57D go hand in hand in treating on conveying machinery; the one handles rubber belt conveyors and shows the different lines of work they can be adapted to, while the latter gives illustrations of conveyors especially built for sawmills, lumber mills and woodworking industries in general.

Injectors

THE HAYDEN & DERBY MANUFACTURING COMPANY, New York.—A new catalogue describing the Metropolitan injectors, H-D ejectors and jet apparatus manufactured by this concern has just been published. It is a carefully prepared book, and contains every possible information regarding injectors and their working.

Railroad Equipments

THE WHITING FOUNDRY EQUIPMENT COMPANY, Harvey, Ill.—A booklet designed for railroad work, illustrating crane installations and other equipments furnished to railroads. A very wide range of service is covered in a very small compass.

Millers

THE CINCINNATI MILLING MACHINE COMPANY, Cincinnati, Ohio.—Catalogue describing the horizontal and vertical high-power millers made by this company. Fine illustrations showing these millers, together with small pictures giving the details and working parts, are given.

Gas Power

WEBER GAS ENGINE COMPANY, Kansas City, Mo.—Brochure No. 58. This is a small pamphlet giving a number of illustrations of recent Weber gas power installations in mills, factories, municipal waterworks and electric light plants. Short, concise descriptions of Weber engines and bituminous and non-bituminous gas producers are outlined therein, making it an interesting booklet for anyone wishing information on this subject.

Drawing Tables

ECONOMY DRAWING TABLE COMPANY, Toledo, Ohio.—This company has just issued a handsome booklet describing a great variety of drawing tables. Among the illustrations are pictures of tables especially designed to meet the requirements of designers, detailers, draughtsmen, engineering contractors, technical schools, etc.

Coal Handling

THE JEFFREY MANUFACTURING COMPANY, Columbus, Ohio.—Bulletin No. 22, devoted to coal tipples and shaking screens. A large number of photos show the wide range of adaptability and great variety of work that can successfully be handled by this machinery.

Heating

GOLD CAR HEATING & LIGHTING COMPANY, New York.—Illustrated catalogue of Gold's improved electric heaters for warming elevated, underground or street railway cars. The general construction of the heaters is shown, together with regulating devices, connections, etc., and methods of installation in railway cars of various kinds. The Gold hot-water car-heating system is also described and the operation of the jet device for accelerating the circulation shown.

Steam Traps

RICHARD J. FLINN, West Roxbury, Mass.—Folder giving description and operation of the Flinn differential steam trap. The subject of its application is also taken up, and the various methods in which the trap can be used described. A table of capacities in pounds per hour is also given.

Water Meter

HAMMOND METER COMPANY, St. Louis, Mo.—A booklet describing the Hammond meter, which is a new machine for measuring water and other liquids under atmospheric pressure. It is especially designed to measure water from condensers and for boiler testing. Meters now in use show errors of less than 1 per cent. The meter is simple in its design, and the working parts are easily accessible. In addition to the sizes given in the tables, this company makes meters of almost any desired capacity to measure the total amount of water pumped by waterworks, etc.

Bearings

THE HILL CLUTCH COMPANY, Cleveland, Ohio.—Collar oiling bearing catalogue.—This is a new catalogue, giving illustrations of the various collar oiling bearings in their mountings made by this company. Table of sizes, prices and code words are also given.

High-Duty Turbine Pump

LEA EQUIPMENT COMPANY, New York, N. Y.—Bulletin G. In this booklet, besides a very comprehensive description of the pump, are also published some very interesting tests made by Prof. J. E. Denton, in which some very remarkable results have been obtained.

Surface Condensers

WHEELER CONDENSER & ENGINEERING COMPANY, Carteret, N. J.—Bulletin No. 102, just published by this company, includes among its contents an interesting chapter on the economy of running condensing, another on the advantages of the several types of condensers, followed by a description of the Wheeler surface condensers, with some remarks on the relative advantages of rectangular and cylindrical shells. A description of the Volz combined feed-water heater and condenser is given, after which there is a section on turbine condenser outfits. The bulletin is profusely illustrated, and cannot but be of interest and value to any engineer who is called upon to design, construct or manage steam plants.

Spiral Riveted Pipe

AMERICAN SPIRAL PIPE WORKS, Chicago, Ill.—Catalogue No. 5 of this company contains many handsome illustrations of different installations, showing the different uses to which this kind of pipe can be put, such as for water mains, exhaust pipes, brine circulation, etc.; but also brings out the advantages of the flexibility of the system—that is, the way in which long-radius curves and slight deflections to conform to grade can be made with bolted joints—and no special degree elbows or bends have to be employed. A good selection of special fittings, together with tables of sizes and prices, appears in this publication.

Metal Plastering Lath

NORTHWESTERN EXPANDED METAL COMPANY, Chicago, Ill.—Booklet gotten up for the use of plasterers, so that they may have at hand reliable information regarding metal lath. The methods of using the Kno-burn expanded metal lath are described at length.

Washing Coal

THE JEFFREY MANUFACTURING COMPANY, Columbus, Ohio.—Bulletin No. 27. This catalogue is profusely illustrated, and describes some characteristic examples of the large number of coal washeries that have been installed by this company.

Electric Control Problems at the Gary Steel Plant.

THE extensive introduction of electric power machinery in the new works of the plant of the Indiana Steel Company, at Gary, Ind., forming a portion of the equipment of the United States Steel Corporation, has led to the development of many interesting features in connection with the control of the various machines. The automatic controlling devices designed by the Cutler-Hammer Manufacturing Company for this work, and now installed at Gary, represent the latest developments in the art of electric control as applied to steel machinery. Thus, in the rail mill there are automatic, remote-control devices for the control of the elevating and tilting tables, the bloom shear and the transfer. The elevating table on the 48-inch blooming mill weighs about 250,000 pounds, and the throwing of a master lever starts this mass from the low-level position and raises it to the high-level position, where it is stopped automatically, the throwing of the master lever to the reverse position bringing the table to the low level again. This operation requires a 250 horse-power motor, and a similar mechanism, driven by a 150 horse-power motor, is used for the tilting table.

The bloom shear at the Gary mills is operated by a 75 horse-power induction motor, and the pin on the clutch by a direct-current auxiliary motor of 5 horse-power. The circuit of the smaller motor is interlocked with the controlling device for the larger one, so that the 5 horse-power motor cannot be operated except when the larger one is running at full speed.

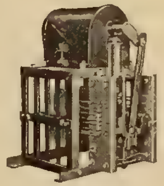
Electrically-operated buggies are installed for transporting the ingots from the soaking pits to the rail mills, each buggy serving six pits. In order to avoid the necessity of the operator stopping the ingot buggy opposite any particular pit, the controlling levers are arranged to be set in six different positions, besides an off position and a position for the mill. By placing the lever in any particular position the buggy proceeds to the corresponding pit, and is there stopped automatically, safety being insured by an interlocking arrangement which insures a clear track for each buggy. Automatic controllers are also installed in connection with the motors on the transfers, making it possible for the operator to transfer a rail automatically from one table to another by a simple motion of a lever.

In order to maintain the load in the power house as nearly constant as possible a regulating system is installed in connection with the storage-battery plant. The various motor-generator sets, converters, etc., comprising this regulating system may be started and stopped from the bench board in the switching gallery by means of remote-control apparatus, and the fields of the various machines may be varied by means of remote-control field rheostats. One of these remote-control starters, used in connection with a motor-generator set which is started from the direct-current end, is believed to be the largest remote-control starter ever built, the rheostat being designed to carry 10,000 amperes with safety under maximum working load conditions.

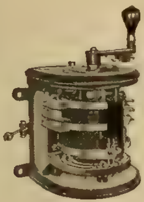
A number of other remote-control field rheostat and field switches are installed in the power house, these representing the latest designs in the department of electric controlling devices, and involving operation either by motor or by hand, thus insuring perfect control under any circumstances; and the entire equipment forms a noteworthy example of the manner in which electric machinery, under the control of a small number of skilled attendants, is superseding the large number of men formerly required in the operation of iron and steel works.

Self-starter for small motor-driven pumps.

Have you not before you NOW some problem in the solving of which our advice would be helpful?



Elevator Controller



Machine Tool Controller

Dynamo Field Regulator

Our belief that we can be of material assistance to anyone confronted with a problem involving the control of electric motors is based on a two-fold reason.

EXPERIENCE: Sixteen years devoted to the study of one subject—and one subject only—electric control.

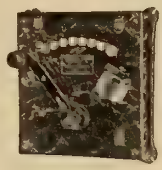
FACTORY FACILITIES: The largest plant in the world devoted exclusively to the manufacture of electric controlling devices.

No man, even though he may be of merely average intelligence, can study one subject for sixteen years without learning a good deal about it.

When, instead of one man of average intelligence, you set to work a score of men trained in the best technical schools of this country and Europe; when you give these men ample facilities for working out their ideas in the laboratory and in the shop; when you scrap—regardless of cost—one piece of experimental apparatus after another until a device is built that pleases not merely one of these men, *but all of them*, it is safe to say that the piece of apparatus so evolved will be the best for the purpose for which it is intended.

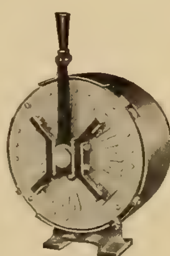
There is today a *standard* piece of Cutler-Hammer apparatus designed to meet every *ordinary* requirement of electric control, and where the requirements are *extraordinary* you will find here trained hands and minds anxious and able to tackle the new problem and solve it to your satisfaction.

Tell us the result you wish to accomplish and if problem falls within the field of electric control we will indicate the best way of securing the desired result and will send you full particulars of necessary apparatus.



Speed Regulator

D. C. Motor Starter



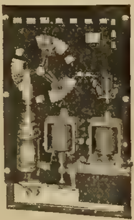
Crane Controller

Printing Press Controller

The Cutler-Hammer Mfg. Co.

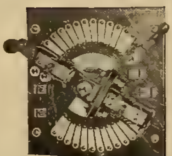
Milwaukee, Wisconsin

NEW YORK Office: Hudson Terminal (50 Church St.)
CHICAGO Office: Monadnock Block. BOSTON Office: 176 Federal St.
PITTSBURG Office: Farmers' Bank Bldg.
PACIFIC COAST AGENTS: Otis & Squires, 111 New Montgomery St., San Francisco.



Self-starter for A. C. Motor

Starting Panel for 1500 H. P. Motor



A. C. Motor Starter

Machine Tool Controller

Electric Power in the Shop

THERE has been much talk about the importance of electric power for the operation of machine tools, and some men have gone so far as to maintain that it is desirable to have each machine in a shop equipped with its own electric motor, thus doing away with all other methods for the transmission of energy. This may be advisable for some establishments, although its general applicability has been questioned. There can be no question, however, as to the desirability of using some kind of power for the transport of materials and of finished products, both in the workshop and between the various departments and buildings of a manufacturing establishment. This fact was first realized in the large iron and steel works, and in such establishments steam locomotives were early used for hauling raw material, ingots, large moulds and castings, and similar bulky and heavy burdens. The smaller shop continued to get along as best it could, often installing some lines of industrial railway, but relying upon human muscle for the propelling power. With the advent of electricity for lighting and for the operation of small tools, it was realized that the electric motor was available for this service, and thus the electric locomotive began to relieve the laboring force of a large portion of its effort.

Some of the earlier electric locomotives were little more than crude applications of the overhead trolley system, similar to that used for street railway service, and involved many inconveniences. The overhead wire causes many inconveniences, and one of the chief advantages in the use of electric power in the shop has been considered to be the removal of overhead obstructions, so that the introduction of the trolley wire could scarcely be considered as a relief. It therefore became necessary to provide some form of electric power transport which should be self-contained and absolutely independent of any other structure. This freedom is secured by the use of the electric storage-battery locomotive, a system which enables a complete line of industrial railway to be installed, not only in the shop, but also in the yards and grounds, permitting an "inter-shop" system to be planned and installed as the development of the establishment demands.

The ease with which an electric locomotive, operating on a well-designed system of industrial railway, can relieve the work of a fully organized laboring gang, is not always realized, and in some cases it is necessary that the equipment shall become disabled temporarily in order that its real value may thereby be appreciated. In one instance which may be cited, through some carelessness of an operative, an electric storage-battery locomotive was run off the track and thus thrown out of service for the time being. As the work could not be delayed, it became necessary to call upon the laboring force to keep things moving, when it appeared that the services of twenty-five able-bodied laborers were necessary to replace the work which had been unobtrusively performed by this efficient machine.

Since the work in most machines is intermittent, it is easily possible to have the battery charged, either during the night, or in such portions of the day as the machine is not required for active service.

Like other mechanical appliances, the electric locomotive is one of those machines which serves to release human effort from a form of drudgery which belongs essentially to inanimate machinery, enabling the man to guide and direct a power which he can use to far greater advantage than his own unaided muscles. The use of such machines marks a forward step in the modern development of the machine shop, a development which is leading to a higher efficiency of all departments of work and reducing wastes, both of time and of money.

The Conservation of Human Energy

WE hear a great deal nowadays about the conservation of natural resources, this convenient phrase meaning that we deplore the way in which other people are wasting the coal, gas, iron ore, timber, and other natural products which we have been accustomed to consider as practically inexhaustible. It is not difficult to talk about this interesting subject in a general manner, but most of us appear to think that it is a matter which somehow concerns the National Government and the people at large, but which we, as individuals, are practically powerless to control.

As a matter of fact, many of us cannot do much to stop the waste of natural supplies of energy and value, except in so far as we can join in the general protest against reckless waste, and thus aid in bringing pressure to bear upon those who have greater influence in these matters than the average citizen. We can stop wastes in other departments of effort, however, if we are so inclined, and sometimes to our own immediate personal advantage. An excellent example of the possibilities of the reduction in the waste of energy appears in the simple question of handling materials, both in the shop and out of doors. There is probably no more brutalizing application of human effort than that which uses, or misuses, human muscle for the direct lifting of heavy weights. Many men have been seriously injured internally because they have endeavored to lift weights which were beyond their limit of elasticity, either because they did not realize the extent to which they were subjecting their muscles to undue stress, or because they were unwilling to acknowledge that they had reached the reasonable limit of their strength.

At the present time there exists a very definite attempt to revise the methods of employing human labor in such a manner as to secure the maximum efficiency of each man in his especial department of work. In other words, the modern works-manager aims to discover the greatest practicable amount of value which he should be obtaining from his employees, and then to ascertain what percentage of this maximum he is actually obtaining from each man. While these efforts have been attended with a certain degree of success, they are necessarily involved in the corresponding efficiencies which are obtainable from the machines with which the men must do their work. It is well understood that the ultimate efficiency of any mechanical operation is the continued product of the efficiencies of the several operations of which it is composed, and hence it is essential that the efficiencies of both the men and the machines involved should be made as high as possible.

In the simple operation of hoisting materials, it is possible to obtain very high efficiencies, but, nevertheless, it is only by the use of the very best appliances that the maximum efficiencies can be secured. Thus, the earlier chain hoists all had efficiencies much below 50 per cent., and this must still be true for all forms of chain block in which the internal resistance by which the load is sustained continues to act during the operation of hoisting. In some appliances, notably in the Triplex chain block, the sustaining resistance is wholly out of action during the application of the hoisting effort, thus permitting hoisting efficiencies as high as 80 per cent. to be obtained, and an application of the same principle permits equally high efficiencies to be secured when electric power is used.

When it is realized that a 50 per cent. man operating a 50 per cent. hoist gives a total efficiency of only 25 per cent., it may be understood that it is as important to secure high efficiency in the machine as in the man, otherwise the job is only half done.

Manufacturing News

Coal-Conveying Machinery Aboard Ship

THAT a mechanical conveyor can be successfully applied to the larger types of sea-going vessels has been demonstrated by the Great Northern Steamship Company in the fueling equipment planned by C. C. Lacey, marine superintendent, for the twin-screw steamer *Minnesota,* plying regularly between Seattle and the Orient.

This vessel, with a gross tonnage of 28,000, is the largest cargo-carrying ship in the world; she is 630 feet long, 73 feet 6 inches beam, 56 feet deep, and is capable of a speed of 15½ knots. In her accommodations for 200 cabin passengers she is equal in all points of excellence to any of our modern floating palaces.

It is evident that the coaling of a vessel so pretentious in all respects as the *Minnesota* is an important factor; it means that the coaling outfit must be strong, rugged and durable;

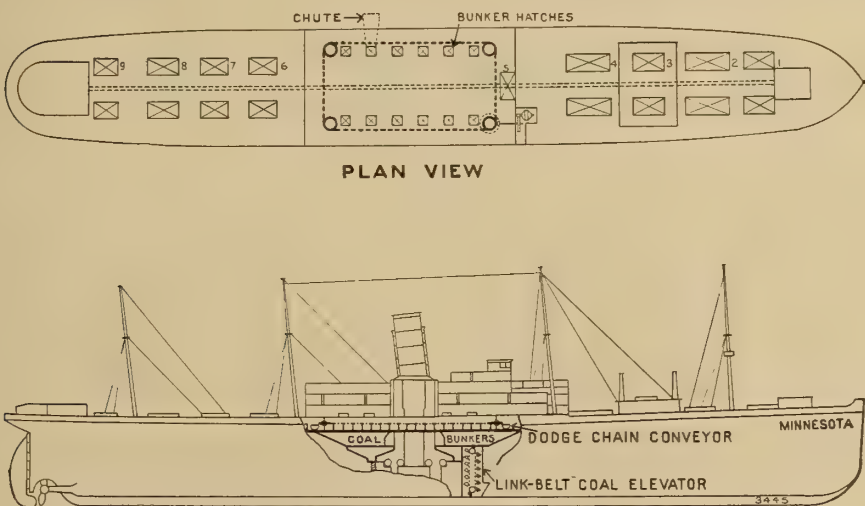


FIG. 1.—ARRANGEMENT OF MECHANICAL CONVEYOR ON BOARD THE MINNESOTA

also the machinery must be compact, in order to fit the small space usually available in ocean steamers. After investigation, these points were decided in favour of the "Dodge" chain conveyor—one of the standard devices made by the Link-Belt Company*: This type of conveyor—well known in engineering practice dealing with transportation of materials on land—has for its principal feature a removable block of malleable iron inserted between the chain links, Fig. 2, and so shaped that the chain may adapt itself to any turn in a vertical or horizontal plane. This feature makes it possible to run the conveyor around a rectangular path in a steel trough under the main deck of the steamship, and serve bunkers, having a total capacity of 3,400 tons, on both sides of the boat.

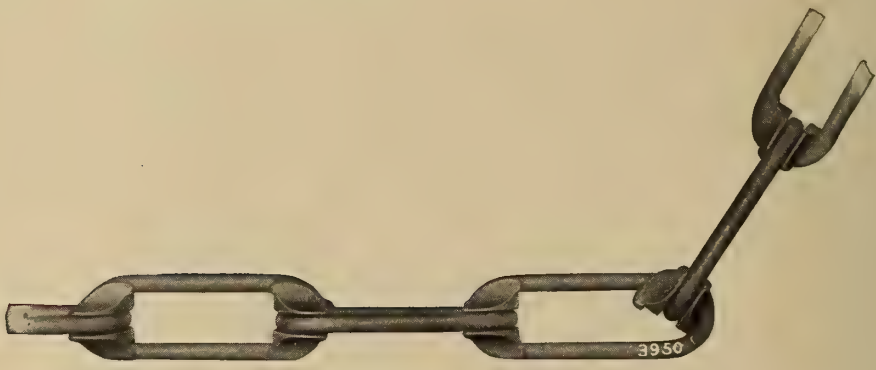


FIG. 2.—CONSTRUCTION OF LINKS TO ALLOW TURNING IN A HORIZONTAL OR VERTICAL PLANE

A longitudinal bulkhead, running the entire length of the vessel and making of it practically two ships, emphasizes the utility of the conveyor, as there is no need of changing the vessel's position or that of the coal barge to procure duplicate broadside loading. Delivery can be made to every part of the bunkers without interruption, or the starboard side may be supplied bv the conveyor and the port side fed direct through the hatch, both operations being simultaneous.

Fig. 1 shows a side view of the machine over the bunkers and a plan of its rectangular travel, in which the longitudinal runs measure 102 feet centres and the transverse runs 68 feet. Steel flights or pushing blades, 8½ inches wide by 20 inches long, are attached to the chain (¾-inch size) at intervals of 33 inches, the normal capacity of the machine being 90 tons per hour, at a speed of 125 feet per minute, bituminous coal of a size that will pass through a 5-inch mesh screen fed to it through hatch chutes.

This delivery is made by means of tub hoists averaging 1,000 pounds of coal at a lift, and at best a somewhat slow and tedious process, but the only feasible method, because of the awkward barges from which the supply is taken.

Notwithstanding these crude facilities, the machine has justified the precedent of its installation by paying for itself in two voyages. The cost of hand-coaling at Seattle reaches as high as $2 per ton—practically a prohibitive price to a vessel such as the *Minnesota*.

Discharge to the bunkers is through the bottom of the conveyor-trough, which is fitted with sliding doors, or gates, each being opened and closed by means of a hand wheel actuating a rack-and-pinion gear.

Provision is made for a reserve storage supply of 1,800 tons forward of the bunkers; this is served by two

* Philadelphia, Chicago, Indianapolis.

"Link-Belt" bucket elevators running in watertight steel casings, and so located as to deliver at the rate of 45 tons an hour directly in front of the boilers.

Each elevator is made up of 7-inch by 12-inch malleable-iron buckets, spaced 16 inches apart on "Ley" bushed chain.

The installation is electrically operated; a 20 horse-power General Electric motor drives the conveyor, and both elevators are driven from a similar motor of 10 horse-power capacity, alternate operation being provided for by clutch on line shaft.

The Dustless Testing Track

THE problem of preserving macadam on motor roadways appeared in its most intense form when the Thomas B. Jeffrey Company, at Kinosha, Wis., undertook to build and maintain a half-mile track for testing their automobiles. It is the custom at this factory to give all the Rambler cars a test of 200 miles' driving on the testing track.

The output of the factory is very large, so that fifteen or twenty cars are running at high speed over the track every hour of the day. Ordinary macadam would, of course, fail under such a test, and the dust would be unbearable, especially at the turns. Various oil treatments and compounds were experimented with, and the Tarvia treatment was finally adopted. It has been found entirely satisfactory. The surface is entirely without dust, is impervious to water, and is so elastic that wear on the tires has been greatly reduced.

The success of tarvia on the Rambler track has been so marked that it has led to the use of this material on all the roads surrounding the factory.

Concrete Floors

THE Vaughan Company, Detroit, Mich., are the manufacturers of a new system of concrete floor construction, which appears to be a movement in the right direction, as it is a development in a practical way of the theoretical basis on which most of concrete floor construction has been figured, namely, the "I" section unit.

An Electrically-Operated Mailing Machine

A LABOUR and time saving device, which finds a wide application in business houses, etc., in handling the outgoing mail, is the electrically-driven envelope sealer, stamper and counter. The machine will readily perform its various operations on 150 letters per minute, and may be speeded up to turn out considerably more when required.

The letters, in bunches, are held against an automatic feed, which permits only one envelope at a time to pass its flap over a metal disk, which revolves in water. As the envelope advances the stamps are fed forward, cut off, moistened and rolled upon the passing letter. After the envelope flap is moistened and the stamp simultaneously attached, the letter passes between a series of rolls under pressure, and then emerges and is automatically stacked. A counter records each stamp as it passes upon the envelope, and thus furnishes a check upon the amount spent for postage. Moreover, the stamps cannot be removed from the machine except by the clerk to whom the key is entrusted.

The source of power being furnished by an electric motor, no mechanical labour is involved in the operation of the machine except the feeding of the letters in bunches. The motor is attached by a flexible lamp cord to an ordinary electric lighting socket, and to start the machine it is only necessary to turn the switch. There is no interruption until the work is completed, and the number of envelopes sealed and stamped in a given time is much greater than is possible in the case of a manually-operated machine.

The Schermack Mailing Machine

Company is the manufacturer of the sealer, stamper and counter, and the Westinghouse Electric & Manufacturing Company furnishes the electrical attachments. Only a ⅛ horsepower motor is required for the latter, so that the charge for current is negligible.

A New Electric Time Recorder

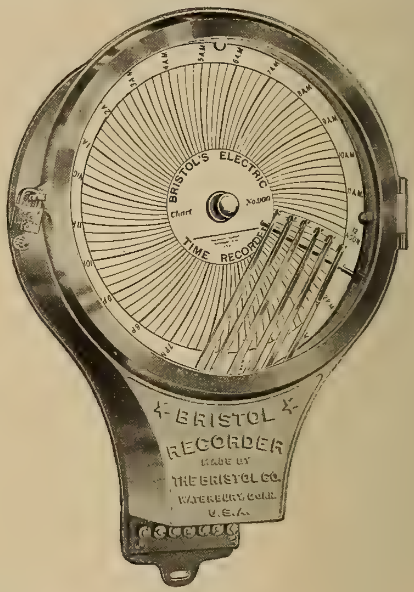
BRISTOL'S new electric time recorder was designed to meet the widespread demand for a simple and practical instrument to record automatically the occurrence and duration of various operations, such as the starting and stopping of machines, the opening and closing of valves, the duration of runs, the passing of trains, etc., etc. With Bristol's electric time recorder it is possible to record several different operations on the same chart, and the recorder may be located a long distance from the points at which such operations occur.

These new recorders have already been used in connection with machinery to show when the machines were started and stopped, how long they remain idle, and just when they were started again.

One of these recorders arranged to record operations at six different points is shown herewith. Each one of the six pens shown on this instrument makes an independent record, continuously and automatically, and in this way six different operations may be recorded on the same chart. Each pen arm is actuated by an independent electro-magnet and battery-circuit, so arranged that closing the circuit causes the pen to move a certain distance on the chart.

Binding posts are provided at the base of the recorder, to which pairs of small lead wires are attached. These wires may be of almost any desired length, it only being necessary to have the object whose motion is to be recorded open or close the circuit whenever the motion occurs.

These recorders are usually operated by a battery circuit, but any convenient circuit may be employed by the insertion of lamps or other resistance to reduce the E. M. F. across each electro-magnet. The object whose motion is to be recorded is



caused to make and break this circuit through any convenient contact.

The Bristol Company, of Waterbury, Conn., are the manufacturers of these recorders.

An American Bridge in Burmah

THE new Scherzer rolling lift bridge across the Ngawun River (Rangoon, Burmah) is completed and opened for railroad traffic. This, the largest bridge constructed in Burma, has a movable span 220 feet long, the total length of bridge being 820 feet. The bridge is constructed on the main line of the Burmah Railways extension connecting Rangoon with Kyngin. The Ngawun River is in the fertile delta of the Irawaddy River, and forms a connection between this river and the Bay of Bengal. The government authorities required the large, movable span to expedite the railroad traffic and the heavy traffic on the river carried on by the Irawaddy Flotilla

Company's vessels, which traverse these waterways from the coast to the interior of Burmah as far as Mandalay—more than 400 miles inland. The bridge was designed by the Scherzer Rolling Lift Bridge Company, of Chicago and New York, and manufactured in England at the works of Spencer & Co., Melksham, Wilts, and erected in Burmah under the charge of the engineers of the Scherzer Rolling Lift Bridge Companly.

The Spencer-Miller Marine Breeches Buoy

THE steamer *Snohomish,* of the United States Revenue Service, the first vessel ever designed and built entirely for life-saving work, while sailing from Norfolk, Va., to the station she is to occupy at Neah Bay, on the Alaskan coast, will be making a voyage nearly 20,000 miles long.

The *Snohomish* carries all the standard life-saving apparatus, but the most important part of her equipment consists of an apparatus designed especially for life saving under conditions which render all other means futile. This apparatus is known as the Spencer-Miller marine breeches buoy, made by the Lidgerwood Manufacturing Company, of New York.

The official trials took place at Arundel Bay, Md., during the week of November 17, 1908, and the officials of the Revenue Service have expressed their entire satisfaction with the life-saving apparatus. The revenue cutter *Itaska* acted the part of a wreck from which rescues were made.

The *Snohomish* was built by the Pusey & Jones Company, at Wilmington, Del., at a cost of nearly $200,000. She is 152 feet long, 29 feet beam, 17 feet 6 inches depth, and draws 12 feet 4½ inches, with a displacement of 795 tons. The engines are of the vertical, direct-acting, triple-expansion type of 1,200 horse-power, driving a single screw and giving her a speed of between 13 and 14 knots. She has one Scotch boiler and one of the Babcock & Wilcox water-tube type. Her coal capacity will enable her to steam 3,000 miles at a speed of 12 knots. The vessel is fitted with electric lights and every comfort available for the captain and crew, including distilling apparatus for furnishing fresh water. She carries a crew of sixteen men, under command of Capt. Levis.

The *Snohomish* has two self-bailing and self-righting life boats and a life raft besides her regular boats, and is equipped with wireless telegraphy, the Ardois system of night signaling, two searchlights, and has a wrecking apparatus for pumping out vessels and a fire-fighting outfit.

Bureau of American Manufacturers in Europe

TO fill a need of American manufacturers for better facilities abroad, a Bureau of American Manufacturers in Europe has been organized in London, and is open to all reputable firms. Foreign buyers visiting London will be invited to attend the exhibition of American goods which will be carried. Monthly bulletins will be sent to buyers in every quarter of the globe, and every mode of advertising consistent with progressive business methods will be employed to make the exhibit a profitable enterprise for the members participating. A staff of experienced salesmen will be engaged possessed of mechanical educations in the lines to be demonstrated. Writing-rooms and conversation-rooms will be maintained, and buyers will be served as carefully and as thoroughly as would be possible at the home offices of the respective members. A comprehensive system of reports between America and Europe will keep the members in close touch with foreign conditions, and it is anticipated that a large increase in exports will attend this new movement.

News Items

Dr. Schuyler Skaats Wheeler, past-president of the American Institute of Electrical Engineers, and president of the Crocker-Wheeler Company, manufacturers and electrical engineers, of Ampere, N. J., gave out the following interview regarding the prospects of the ensuing year:

"It is not reasonable to expect that business will immediately return to normal merely because the outlook at the present time is bright. A complete resumption of business cannot occur rapidly, and it may be months before conditions in the business world are what they were before the financial panic of a year ago. However, every feature of the situation is favourable at the present time. Factories are starting up, more men are being employed, and there is a better market than there has been for fourteen months for all kinds of machinery. I am looking forward during 1909 to a complete recovery and more and better business than we have yet had.

"At this time those companies like the Crocker-Wheeler Company, which have at great expense retained their organizations and personnel, including highly-trained designers and sales engineers, during the lean months of 1908, are now reaping the benefit of this policy, and are in a position to go forward faster and with greater effect than is possible for the concerns that have been obliged, through forced economy, to reduce their organizations and discharge many of their good men."

The Cornell Economizer Company announce their removal from their old offices at 625 Witherspoon building, Philadelphia, Pa., to 55 De Long building, on the southeast corner of Thirteenth and Chestnut streets, Philadelphia.

The next monthly meeting of the American Society of Mechanical Engineers will be held in the Engineering Societies building on Tuesday evening, January 12. The paper will be by Carl G. Barth, of Philadelphia, upon "The Transmission of Power by Leather Belting," illustrated by lantern slides.

Macarthur Brothers Company, of New York, contractors, has organized a "Department of Statistics," for the purpose of obtaining the best and earliest information on new construction contracts and any important information interesting to contractors.

The Raymond Concrete Pile Company, of New York and Chicago, has been awarded the contract for placing Raymond concrete piles in the foundations of a compressor house that is being erected at the Erie Basin, Brooklyn, for the John N. Robins Company, Wm. T. Donnelly, engineer; C. F. Bond Company, general contractors. Another contract awarded to the Raymond Company calls for the placing of Raymond concrete piles in the foundations of Public School No. 17, which will occupy a site extending through from West Forty-sixth to West Forty-seventh street, between Ninth and Tenth avenues, New York, C. B. J. Snyder, architect Board of Education; Clark & Stowe, general contractors.

At the meeting of the Westinghouse Electric & Manufacturing Company held at East Pittsburg November 30, 1908, final action was taken by the stockholders prior to the termination of the receivership. The object of the meeting was to pass resolutions amending the by-laws so as to allow of the election of sixteen directors, to classify the directors into one, two, three and four-year terms, and to provide for the election of a proxy committee.

The following board of directors was elected. For the one-year term, Richard Delafield, E. C. Converse, Anthony N. Brady, J. D. Callery; for the two-year term, A. G. Becker, Geo. M. Verity, William McConway, Charles A. Moore; for the three-year

term, Charles F. Brooker, James S. Kuhn, Edward F. Atkins, E. M. Herr; for the four-year term, George Westinghouse, Neal Rantoul, Joseph W. Marsh, Albert H. Wiggin. The proxy committee consists of James N. Jarvie, Jacob H. Schiff, Charles Francis Adams, Robert S. Smith and F. W. Roebling.

An order has been received by the Nernst Lamp Company for three-glower lamps to replace the six-glower Nernst lamps in the corridors of the Frick building, Pittsburg.

Nernst lamps have been used in this magnificent building for the past five years; the new lamps will give the same volume of light as the old at a saving of 25 per cent. in the current consumption. Besides this, they have the advantage of greatly simplified renewal at a material reduction in cost.

The Estey Organ Company, Brattleboro, Vt., has just placed with the Crocker-Wheeler Company, of Ampere, N. J., an order for fifty-seven induction motors, ranging from ½ to 75 horse-power, together with seven transformers and a switchboard. Current will be purchased from the Connecticut River Power Company. Some of these motors will be used for driving individual machines and others for driving line shafting.

The Blackburn-Smith feed-water filter and grease extractor, made by James Beggs & Co., New York, has been chosen for the new colliers—*Mars*, *Hector* and *Vulcan*—now being built for the United States Navy by the Maryland Steel Company. These ships have the highest class of equipment and every possible protection. The filters are to be placed in the feed lines, so that every drop of water entering the boilers is subjected to double filtration.

The largest construction contract that has been let since the Chelsea fire has just been awarded to Frank B. Gilbreth, general contractor, New York. The contract, which calls for the rebuilding of the entire box-making plant of the Atwood-McManus Company, which was destroyed in the second Chelsea fire, will involve the construction of a power plant with two very tall chimneys, a receiving building 345 feet long, located on the Eastern division of the Boston & Maine Railroad, an office building, a stable 200 feet long, a sawdust and kindling wood building, a two-story factory building, 350 feet long by 200 feet wide, and a warehouse, 375 feet long by 68 feet wide. About 800 men will be employed in the work. Lockwood, Greene & Co., of Boston, are the architects and engineers.

Mr. J. E. Woodwell, of the firm of L. B. Marks, & J. E. Woodwell, New York City, has been retained by Messrs. McKim, Mead & White, architects, as consulting engineer for the entire mechanical and electrical equipment, including the heating and ventilation, electric lighting and power, mail-handling devices, etc., of the new United States Post Office to be erected at the Pennsylvania Terminal Station in New York City. The cost of this installation will be upwards of $500,000. The firm has retained Prof. S. H. Woodbridge, of the Massachusetts Institute of Technology, as associate consulting engineer for the heating and ventilation of this building.

Mr. W. B. McVicker has resigned as vice-president and Eastern manager of the Dearborn Chemical Works. He has incorporated the W. B. McVicker Company, with offices in the United States Realty building, 115 Broadway, New York. A new and complete laboratory and factory are in course of construction, and is about completed.

The personnel of the company includes Charles M. Eddy, Albert E. Carpenter, Joseph F. Hammill, William J. Schatz, G. Frank Duemler and Frank J. Zink.

THE LATEST CATALOGUES

Thermit

Goldschmidt Thermit Company.—Booklet on the application of thermit in foundry practice. The thermit process is here described and the advantages of this process for the reviving of dull iron or steel, the melting of steel scrap (borings or punchings of cast iron), the production of semi-steel, the prevention of piping in crucible-steel ingots, and the successful manufacture of small steel castings pointed out. An extract of a report on the method used to avoid piping in steel ingots, as applied in the Hungarian Government Steel Foundries at Diosgyor, is also given.

Electric Time Recorder

The Bristol Company Bulletin No. 89, describing a new electric time recorder made by this company. This recorder should prove to be a very useful addition to the instrument equipment of any plant or power station to give complete records of the starting and stopping of engines, motors and generators, opening and closing of valves, and some twenty or thirty other operations, too numerous to mention here.

Friction Clutches

The Hill Clutch Company, Cleveland, Ohio.—Catalogue G, describing and listing friction clutch pulleys and couplings, together with the necessary accessories and extra parts.

Heating and Ventilating

Buffalo Forge Company.—Catalogue 197. With this number as a title, the Buffalo Forge Company have just issued a new catalogue. It is made up of four parts, the first two of which take up the heating and ventilating of public and industrial buildings, the third one describes the Buffalo heating and ventilating apparatus, while the last one gives data on heating and ventilating. The whole catalogue is very carefully arranged, and gives an exhaustive description of the Buffalo fan system, together with many illustrations.

Chain Blocks and Electric Hoists

Yale & Towne Manufacturing Company, No. 9 Murray street, New York.—New catalogue, describing chain blocks, trolleys and cranes and electric hoists, together with their latest improvements.

Coal Crushers

Pennsylvania Crusher Company, Philadelphia, Pa.—Catalogue No. 11, a high-class publication regarding hammer crushers, rotary crushers, rock crushers and magnetic separators.

Machine Tools

Pratt & Whitney Company, Hartford, Conn.—Two handsome catalogues describing milling machines, die sinkers, profilers and multiple drills.

Feed-Water Regulators

The American Boiler Economy Company, Philadelphia, Pa.—A well-illustrated booklet describing the Copes boiler feed regulator and its various advantages. A perusal of this publication might be of much interest to consulting, designing and managing engineers.

Fans

B. F. Sturtevant Company, Hyde Park, Mass.—Bulletin No. 158 has just been issued. In it the very latest developments in the designs of mine fans, steam fans, turbine fans, etc., are published.

Air Compressors

National Brake & Electric Company, Milwaukee.—Publication No. 386, regarding air compressors for industrial service, is their latest catalogue.

Transformers

Westinghouse Electric & Manufacturing Company.—The type S distributing transformers are fully described in Circular No. 1,157.

Fort Wayne Electric Works, Fort Wayne, Ind.—A practical guide for transformer testing just published by this company, giving the most up-to-date methods of transformer testing in a way which is at once simple and comprehensive, and therefore should render the publication a valuable aid to the practical central station engineer.

Steam and Oil Separators

Pittsburg Gage & Supply Company, Pittsburg, Pa.—This company have just issued a small catalogue, as well as some small folders, describing their various styles of steam separators, as well as the "White Star" oil filter, made by this company.

Fan Motors

General Electric Company, Schenectady, N. Y. — Bulletin No. 4,632. This catalogue, called Fan Motors for 1909, contains illustrations, descriptive matter and prices of the entire line of General Electric fan motors for the coming season. This line embraced motors for both alternating and direct current, in desk, bracket, ceiling, floor column and counter-column types of standard sizes. It lists also ventilating motors and miscellaneous small-power motors for alternating and direct current, as well as various supply parts of the standard General Electric fan motors.

Steam Gauges

The American Steam Gauge & Valve Manufacturing Company, Boston, Mass.—Illustrated catalogue devoted to gauges, valves, indicators and kindred appliances for governing, measuring and recording steam, water, air, gas, ammonia and all other pressures. Illustrations and full details are given.

Manila Rope

C. W. Hunt Company, West New Brighton, New York.—Pamphlet No. 082, giving illustrations and descriptions of the various uses that "Stevedore" manila rope can be put to, such as for the transmission of power, pile-driving and hoisting.

Boilers

The Bird-Archer Company, 90 West street, New York.—A book, entitled Boiler Troubles, has just been published by this company. In it are discussed their causes, their effects, and the methods of preventing these troubles. The book should prove of great value to steam users.

Nernst Lamps

Nernst Lamp Company, Pittsburg, Pa.—Bulletin B, describing at length the Westinghouse-Nernst multiple-glower lamps, and giving the code words for the various styles.

Machine Tools

Manning, Maxwell & Moore have just published their new machine tool catalogue. The tools illustrated and described in it are grouped most carefully, to enable any one examining the book to most conveniently investigate the different lines of machine tools, etc., represented therein. For example, the first 125 pages of the catalogue are devoted exclusively to a general line of tools for service in railroad machine shops. A large section of the catalogue is devoted exclusively to electric traveling cranes, dock cranes, wrecking cranes and other similar devices. These two examples give a clear idea of the general grouping which has been followed out in the compilation of this catalogue.

The American Bank Note Company designed the book and produced it for Manning, Maxwell & Moore. The workmanship shown in the text and the excellence of the cuts all speak most emphatically for the care and expense given to the production of this catalogue.

Labour-Saving Machinery

IT is rather interesting to observe that the earlier attempts to perform operations by machinery were directed towards those lines of industry which were by no means the most laborious. Textile machinery, wood-working, harvesting, machine-shop operations — these were first devised and much ingenuity successfully applied to do mechanically the work which had formerly been accomplished wholly by human effort. The success which attended the introduction of machinery into the factory led to further attempts to replace the man by the machine, and now there are few difficult and laborious operations to which mechanical devices have not been applied.

The handling of materials naturally attracted the attention of the engineer, and this department of work includes not only the materials of construction, but also what have been termed the materials of consumption, such as the various kinds of fuel, wholly or partially consumed in their transformation from the condition of latent stores of energy into active producers of heat and power. To this important portion of mechanical engineering much able effort has been given, with the result that it has become possible to install great power plants, requiring the handling of immense quantities of fuel, with a number of men far below that which would have formerly been considered necessary.

There is probably no more laborious work than that of handling coal, both in the loading and unloading of barges or cars and in the feeding of boiler furnaces. To replace this by mechanical appliances is thus to effect the solution both of an industrial and a sociological problem, and in this respect that engineer has achieved an important development in general progress. At every great power station and in many isolated power plants there can now be seen complete equipments both for bringing the coal to the furnaces and for conveying the ashes away.

In modern fuel-handling machinery automatic methods have been extensively applied, this enabling a portion of the manual labour to be omitted, and insuring a higher degree of efficiency than is possible with less highly organized equipments. Thus, an automatic railway may be installed to take the coal which has been lifted from a barge or car and deliver it to bins over the boiler room, depositing it at whichever bin the operator may select. In like manner coal may be taken from a main storage bin in predetermined quantities and delivered by automatic or cable railway, as desired. Similar methods are applied in the conveying of ashes, and the result is that cleanliness and efficiency exist where, under earlier conditions, there were dirt, dust and the hardest kind of manual labour.

In the earlier days of the introduction of labour-saving machinery it was assumed that, because the mechanical appliances did the work of many men, they were opposed to the interests of the workingman. This idea, although naturally that which would first occur to the man who had been displaced by a machine, is by no means true. The actual effect of the general introduction of labour-saving machinery in all departments of work has been to permit and encourage the development of great industrial enterprises, giving employment to far greater numbers of men than had been displaced. This is the fact in nearly every line of work in which improved machinery has been introduced, and it is true of coal handling as it is true in the steel mill, the harvest field and the manufactory. In addition to the increased developments thus effected by the introduction of labour-saving machinery we must remember the new work created in the manufacture of the machinery itself, so that the replacement of manual labour by the machine has proven beneficial both to employer and employee.

Aids to Skilled Labour

IN the general tendency towards the replacement of the effort of men by mechanical appliances the fact must be observed that it is the unskilled and the moderately skilled who are continually being displaced. It is always the highest kinds of work which is the most difficult to perform entirely by machinery, and this will continue to be true until some mechanical appliance shall be discovered which will take the place of human brains and intelligence.

The old-time machine shop always had what was termed the "labouring gang," and, while a certain amount of labouring force is still necessary, it has been greatly reduced in numbers and materially increased in efficiency at the same time by the introduction of labour-saving appliances. When it is remembered that formerly by far the greater part of the time consumed by a mechanical operation was that required for the placing of the work in the machine, in its setting, and in its removal, the gain to the skilled workman is evident.

It is only by the use of modern appliances and methods for lifting and handling work in the shop that the highest benefits can be gained in the introduction of improved methods of remuneration both for the workman and for the employer, since it is possible for the skilled mechanic to push his work only when he is free to devote his full energies to the actual conduct of the machining operations. This means that the modern shop must be equipped not only with modern tools, but with modern appliances for handling the work, including cranes and power-hoisting machines, together with hand-operated hoists of maximum efficiency and convenience.

The modern tendency is to consider the whole subject of efficiency in every department, establishing standards not only for the tools, but also for the men, skilled observers determining the output of which machines and machinists should be capable, and then comparing these full efficiencies with the actual results. In many instances this method has resulted in showing that establishments in which the administration was considered most effective were really far below the degree of efficiency which was readily attainable.

The extent to which the efficiency of the man is bound up with that of the machine is seen when the general rule of the ultimate efficiency of a series of operations is considered. It is very unusual for an efficiency of 100 per cent. to be attained in any operation; and when, as is usual, more than one operation is to be performed upon any piece of the work, the final efficiency is the product of the several efficiencies of which the whole is composed. If an engine having an efficiency of 12 per cent. is operated in connection with a boiler having an efficiency of 80 per cent., the combined efficiency is the product of the two percentages, or only 9.6 per cent.

In the same manner a piece of work subjected to two operations in which efficiencies of 40 and 60 per cent., respectively, are attained, the final efficiency is only 24 per cent., being the product of the two. The result, when a number of operations are considered, is amply sufficient to account for the very low efficiencies which are found in many shops in which the detailed operations seem to be conducted in a fairly efficient manner.

Bearing these fundamental facts in mind, the importance of securing high efficiency in such an appliance as a hoist, upon which the effective performance of a high-priced machinist, operating an expensive machine, may depend, will be appreciated. The handling of the work, lifting pieces in and out of a lathe, or to and from the bed of a planer, including adjustment, demands apparatus equal at least in efficiency to the lathe or planer itself, and it should be as high as that of the man whose time and effort wait upon its performance.

Engineering and Prosperity

IT is well understood that the wealth and prosperity of a nation are intimately connected with its industrial activity; but this, in turn, must depend for its development upon the creation of new wealth. Men can appear to be busy, and can be busy, trading with each other; but if the property merely passes from hand to hand its value cannot change greatly unless some work is also put into it which affects its usefulness.

Every year there is added a fresh contribution to the wealth of the world represented by the new material which is wrested from the bosom of the earth by the efforts of mankind. This is real, new wealth; wealth which existed before only in a latent condition; wealth which would have remained latent but for the exertion of human effort.

Formerly nearly all this new wealth came from the agriculturist; the farmer added his crops to the product of previous years, and other people traded in them until another year brought a fresh supply. This is still true to a large extent; but the development of modern industry has not only added many other things to the vegetable products of the soil, but has also made possible the development of agriculture to an extent formerly impossible. To the crops of the farmer is added the output of the mines, quarries, forests and oceans. Again, to these products added value is given by transporting them from points where they can be obtained to the places where they can be used. Still further value is created by the development of new uses for things formerly neglected; and thus the wealth of the world is increased not only by the effort of a man's muscles, but also by the labour of his brains.

Labour is almost wholly dependent upon engineering for the opportunity of employment, and every new engineering triumph opens fresh fields for labour and adds to the opportunities for extended service and remuneration.

Thus it becomes evident that prosperity is intimately bound up with the work of the engineer, and to-day the most profitable fields for the employment of capital are those which are based upon engineering work. It is the engineer to whom the capitalist turns for a report upon the mine, the invention, the manufacturing process; and when the capital is invested, it is the engineer again who must keep it at work earning the dividends which alone can justify the investment.

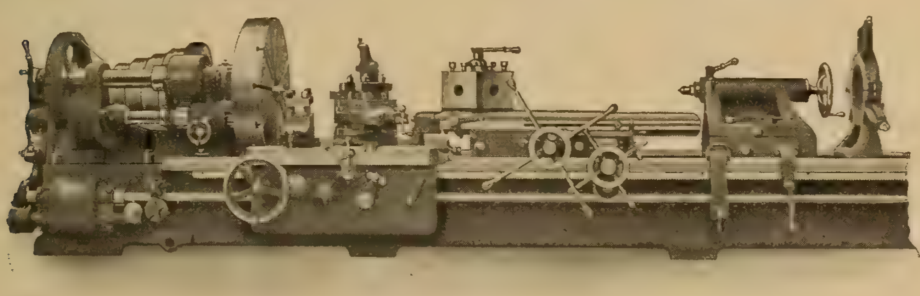
When industrial relations are disturbed, the work of the engineer, with that of all other busy men, is naturally impeded, and the result is a diminution in the production of that new wealth upon which future prosperity depends. Capital, which alone can give him the opportunity of exerting his productive activities, is withdrawn from him and hoarded, thus not only being kept idle, but keeping others idle. Dull times necessarily follow, and, as in many other cases, the effect is also the cause, and the involuntary idleness of the men by the activity of whose brains prosperity can alone be created is followed by the involuntary idleness of employees, producers, shippers and business men.

When, on the other hand, opportunity is offered for the engineer to create new outlets for human and financial energy, prosperity immediately follows. Existing wealth, permitted to be put in motion, enables new wealth to be created; and, like the snowball of the schoolboy, the accumulation proceeds at an ever-increasing rate, dull times vanish, prosperity becomes widespread, labour is employed and dividends are earned.

Manufacturing News

36-Inch Heavy Pattern Triple Geared American Lathe

THIS lathe is one of the finest examples of high-class machine-tool design and workmanship, its alignments are perfect, and it is so designed as to insure extreme ease of operation. The machine is steel geared throughout, and of very heavy construction, the back gears are automatically disengaged when slipping pinion into internal gear and vice versa. Longitudinal feed of carriage is controlled by a friction, and the cross-feed by a saw-tooth clutch, operated from "star" handle on the apron; which is "cam-actuated." Rack pinion in apron can be withdrawn while thread cutting. Feed box, on front of machine beneath head stock, supplies three (3) instantaneous changes for feeding and screw cutting, for every change of gears on quadrant at head end of lathe. Gears are covered wherever possible, and all loose running gears are bronze bushed. Compound rest is fitted with "four-stud" tool holder, with tool resting on a serrated steel base. Tool is clamped by the four nuts and two straps, which straps may be set in the opposite direction. Compound rest may also be fitted with double T-slotted top-slide and equipped with regular tool posts set in tandem, which prevents slippage of the cutting tool, under heavy strains, and subsequent spoiling of the work.



HEAVY PATTERN, TRIPLE GEARED AMERICAN LATHE. THE AMERICAN TOOL WORKS CO., CINCINNATI, OHIO.

The turret is of new design

throughout, possessing many new and valuable features. It is equipped with our new "indexing mecnanism," which is self-compensating for wear. This mechanism is located at the front of turret top-slide, which brings the locking-pin very near to the tool. This is superior to turrets of other makes, which locate it at the back, in which position any slight wear is multiplied many times by the increased distance of the cutting tool.

The bottom-slide of turret is moved along the bed by the pilot wheel, shown at near end. It is clamped to bed by two eccentrics, one at the front end and the other at the rear end. It is further secured from slipping, due to severe end-thrust, by a pawl, which, dropping from the turret, engages a ratchet-toothed rack cast in the center of the lathe bed.

Eight well-selected feeds are supplied to the turret, ranging from .005 inch to .162 inch, which are entirely independent of the regular carriage and apron feeds. Turret feeds are controlled by the two "star" knobs, carrying index dials, which are shown one directly above the other on the front of the bed near the feed box. The dials and pointers thereon indicate at once the feed in inches as set, and all changes can be made while the lathe is running. The "star" knobs operate through shafts, extending through the bed to the quick-change turret-feed-box at the rear of head-stock, which is provided with a neat and substantial cover.

Feeds of turret can be reversed which is a valuable feature when wishing to "back-face" or "counterbore." Reversal of feeds is controlled by the lever, conveniently located on driving sprocket of quick-change turret feed-box.

The taper attachment is of very heavy construction and so designed as to eliminate all binding tendencies of the parts, thereby insuring smooth and uniform action. It is given a support on the bed and is supplied with a vernier attachment to facilitate very fine adjustment. It is graduated and the entire attachment bolted to and travels with the carriage. May be quickly engaged or disengaged at will, without disturbing the taper as set.

There are, besides the features mentioned above, a great number of decided improvements too numerous to mention here, but full information can be obtained by applying to the manufacturers, who are the American Tool Works Company, Cincinnati, Ohio.

An Improved Pneumatic Tool

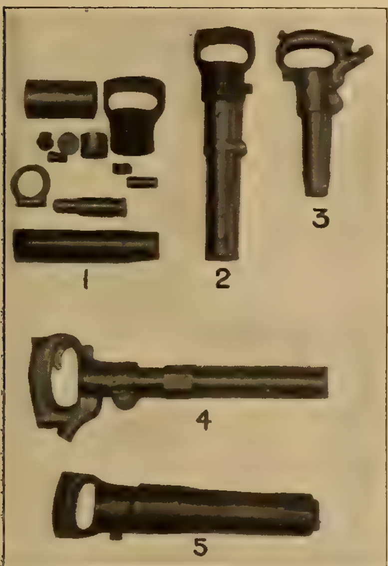
THE value of pneumatic tools for many varieties of work is leading to continual improvements in this class of machines, and we illustrate herewith one of the latest of such tools, about to be placed upon the market by the I X L Manufacturing Company, of New York, a factory having been established at No. 584 Hudson Street, New York City.

The illustration shows the tool and some of its parts, and it may be noted that the particular tool there exhibited has drilled eight holes, 3 inches in diameter, for a depth of 6 feet in solid granite, a feat which, it is claimed, has never before been accomplished with a tool of this style. The tool with which this result was achieved has a piston of 1 3/16 inches in diameter, and a stroke of 2½ inches, and is the one shown at Fig. 5 in the illustration. In the same illustration, at Fig. 1, are shown the parts of a No. 1 driller, this giving an idea of the simplicity of construction which obtains with all of the tools of the I X L Company. This tool, when completely assembled, is shown at Fig. 2. At Fig. 3, is illustrated a small metal chipping tool, suitable for light chipping work, as in foundries, and two other larger sizes of this tool are also made.

The usefulness of the pneumatic tool for riveting is well known, and

at Fig. 4 a medium-size riveting hammer is shown, this being designed for rivets up to ¾-inch in diameter, there being three other sizes in this series, taking rivets up to 1¼ inch.

It is intended by the manufacturers to extend the line of pneumatic tools by making a complete line of tools for working stone, including two sizes of surfacers, five sizes of carving tools, three sizes of chipping tools, as well as rock drills, air-feed mining drills, sand rammers, and a number of other varieties.



IXL PNEUMATIC TOOLS

An important question in the life of pneumatic tools appears in the friction of the working parts, and this feature has been given especial attention in designing the tools here illustrated. One of the especial features of the I X L tools lies in the reduction of friction to a minimum, this not only giving the tool a longer life, but also minimizing the vibration.

The advantages of the I X L pneumatic tools may thus be summed up as follows: simplicity of construction, reduced friction, reduced vibration, longer life and greater productive capacity.

New Design of Surface Condenser Mounted over Combined Air and Circulating Pumps

THIS apparatus is especially recommended for locations where the water supply for condensation is salt or unfit for boiler feed, and where it is desired to save the condensed steam for that purpose. It will readily maintain a vacuum of 26 inches referred to a 30-inch barometer when supplied with sufficient cooling water.

The cylindrical condenser is mounted on top of a direct-acting combined air and circulating pump, the three cylinders of which are in a straight line; the steam cylinder in the center and the air and water cylinders at each end. By this arrangement a very smooth and steady running pump is ensured, as the regulating action of the water pump equalizes the irregular load on the air pump.

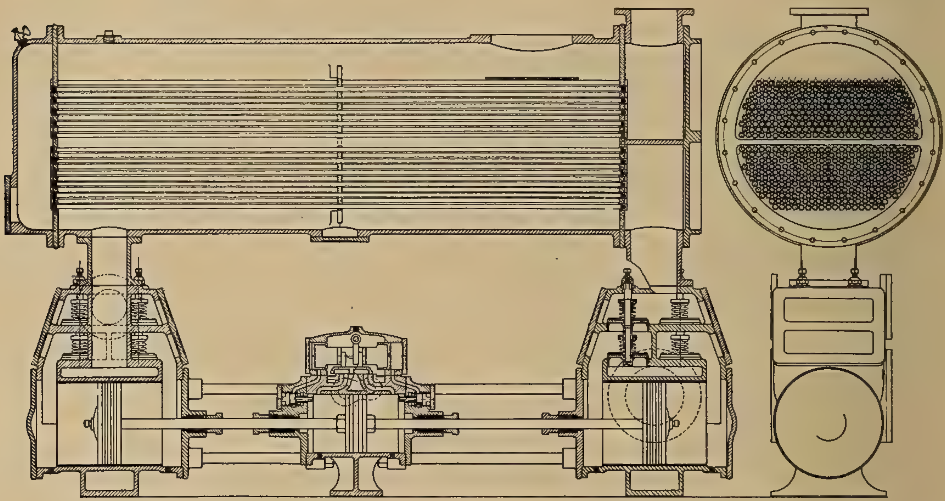
The water chamber of the condenser rests directly on top of the water cylinder and the circulating water passes upward from the water cylinder and through the lower bank of tubes, returning through the upper bank and out at the highest point of the water chamber. The arrangement is such that no air can lodge in the condenser tubes and impair their efficiency. Exhaust steam entering the top of the condenser near the circulating water outlet spreads along the entire length of the condenser before passing on its course down through the tubes, where it is condensed and finds its way by gravity to the air pump as condensed water, air and non-condensible vapors.

The condenser shell, water chamber and covers are cast iron. The tubes are seamless drawn brass and are secured at each end into Muntz metal tube plates by means of brass screw glands packed with corset lace packing. The tubes are free to expand and contract but are held from getting out of place endwise by a shoulder in the screw glands. Where the tubes are long, they rest

in a support plate placed midway in their length. In all cases they are relieved from any impact of incoming steam by a baffle plate placed opposite the exhaust steam inlet. The condenser can be opened up and inspected without disconnecting any of the pipe connections.

The steam cylinder is of the well-known Cameron type with no outside valve gear, and makes its full stroke every time. The steam cylinder heads are removable without dis-

The A. S. Cameron Steam Pump Works are prepared to build all sizes of surface condensers up to 1,500 H. P., and can furnish condenser shells of sheet steel or copper where lightness is a factor; or pump ends of all brass if desired. Where there is not sufficient head room, the condenser may be placed alongside the pump, but in all cases it should be high enough for the condensed water to flow by gravity to the air pump.



SECTION OF CAMERON SURFACE CONDENSER MOUNTED OVER COMBINED AIR AND CIRCULATING PUMPS

connecting any of the other parts. Both pump cylinders are brass lined and are fitted with brass pistons arranged for fibrous packing. The piston rods are of Tobin bronze and separate at the steam piston. The valve system in both air and water cylinders is of the usual Cameron arrangement. By removing the cover at each end of the cylinder every valve is exposed to view. Each valve stem holds two valves with their springs one above the other, so that by simply unscrewing one plug and pulling out the stem both are released. The air and water cylinders are in the most accessible position for inspection and repairs, and the air piston and valves are submerged at all times.

MANY attempts have been made to perfect a magnet for handling pig iron and scrap, inasmuch as the large amounts of such raw material handled by tedious hand methods at all steel and iron works and foundries offered a tremendous field for the saving of labour, providing a practical lifting magnet could be developed for the purpose.

Perhaps the first experiments in this direction which gave promise of commercial results were made at the West Seneca plant of the Lackawanna Steel Co. under the direction of Mr. E. D. Edmondson and Mr. L. R. Palmer, a lifting magnet being constructed which actually lifted pig iron, though in rather small quantity,

taking into consideration the weight of the magnet and its current consumption.

The first commercially successful lifting magnet for handling pig iron, scrap and miscellaneous magnetic material was placed on the market by the Electric Controller & Mfg. Co. in March, 1905. This magnet was built in two sizes, commercially known as No. 1 and No. 2, Type S magnets. Over 150 of these magnets have since been placed in service and at a conservative estimate saved to the iron and steel trade of this country at least half a million dollars in the cost of handling material within the past year. This type of magnet has also been introduced in Germany and England.

Unquestionably a successful lifting magnet must withstand in service more severe abuse and rough handling than any other type of electrical apparatus. In operation it is suspended from the hook of a crane (frequently not equipped with a lowering brake), and may be dropped at high speed upon the material to be lifted, which may be comparable almost to dropping the magnet from a second-story window. In service it will be swung against cars, charging boxes, piles of pig iron, etc., and must be capable of withstanding the blows and shocks which result. It must operate under all weather conditions, day or night, irrespective of rain or snow, and its insulation must withstand a voltage much higher than line voltage, due to the inductive kick which occurs when the circuit of the magnet is opened. Its winding must not be injured by the large amount of heat which is necessarily generated within it, but preferably also should not be damaged by external heat when the magnet is called upon to handle hot material.

A NO. 6 TYPE S-A MAGNET LIFTING SEVEN BUNDLES OF SCRAP WIRE (WEIGHT 1,750 POUNDS) AT THE CARNEGIE STEEL COMPANY'S PLANT, HOMESTEAD, PA.

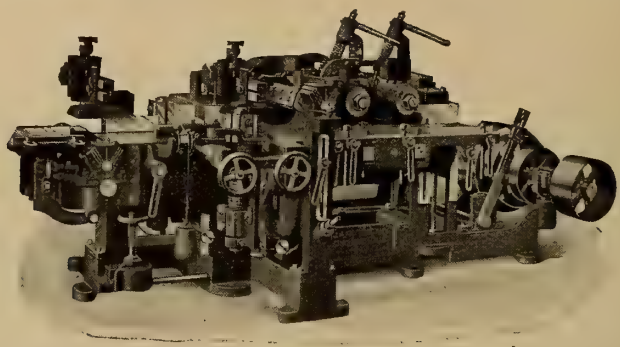
The construction of the magnet also permits of great flexibility and at the same time makes it impossible for the flexible leads which connect

to the two ends of the magnet winding to come into accidental contact. These features of construction indicate how carefully the design of Type S.A. magnets has been thought out and worked out from a mechanical and electrical standpoint.

In addition to the structural features the Electric Controller & Mfg. Co. have incorporated in the design of Type S.A. magnets the results of long experience and careful study of the best proportions for securing maximum efficiency in handling material.

By maximum efficiency is meant the ability to handle the largest amount of material in a given time with minimum total consumption of current. In this respect the results obtained with Type S.A. magnets far surpass any results which have been obtained in the past. As an instance, the No. 4 Type S.A. magnet, 40 inches in diameter, lifts substantially as much as older forms of magnets of 50 inches in diameter with substantially the same current consumption, but weighs 2,000 pounds less. Comparing the performance of the two magnets on a 5-ton crane having 25 H. P. hoist motor, with equal lifts, the No. 4 S.A. magnet has the advantage of 2,000 pounds in total load to be lifted, or 20 per cent. of the total hoisting capacity of the crane. This will mean a saving in current consumption of 20 amperes on the part of the hoist motor, and by virtue of this lower current consumption and lighter load the hoisting speed will be higher and the amount of material handled in a given time will be materially increased.

Proportionable increases in efficiency are shown by the No. 5 and No. 6 Type S.A. magnets, the No. 6 magnet being without question the most powerful commercial lifting magnet which has ever been constructed.



HEAVY FOUR-SIDE MOLDER. J. A. FAY & EGAN, CINCINNATI, OHIO

Heavy Four-Side Molder

AN interesting machine for woodworking is the one shown on this page. It is what is termed a four-side molder and is designed for extra heavy molding.

It is made in two sizes, to work material 12 inches and 14 inches wide.

The frame is a heavy cast-iron structure built up and mounted on a substantial sole plate made extra long to insure best belt service.

The bed raises and lowers by powerful screws mounted on ball bearings. It drops to the depth of 12 inches and is securely locked in any position. The section of the bed after the lower head swings down out of the way gives access to the head.

The cutter heads are of crucible steel, four-sided and slotted on each side. Upper head has adjustable, detachable outside bearing, with an upright column extending from the floor. Lower head has vertical and lateral adjustments.

Sectional clamp bearings are applied to both the upper and lower cutter-head spindles. These bearings consist of metal plates held in position by clamp bolts, which exert no downward pressure on the journals, and which cannot be screwed tight enough to bind, as is often the case with the old-style cap boxes. Any wear that may occur can be quickly taken up by releasing the clamp bolts and simply pressing the plates down with the hand. This device always insures a cool-running journal.

The chip breaker is adjustable and slides back out of the way, the pressure bars after the upper and over the lower heads both swing up out of the way, and the device is so arranged that without readjustment it will return to its original position.

The side heads are mounted on the table and have independent, vertical, lateral and angular adjustments, all made from front of the machine. The outside side head is fitted with improved weighted matcher clip, which with the fence is arranged to move simultaneously with the spindle and head.

The feed consists of four powerfully geared rolls— two upper ones of spur sections and two lower ones solid. The upper rolls are both driven down, which enables the company to apply their patent spring hold-downs, giving an even pressure on the material and in every way much more powerful and satisfactory than the old system of weights and levers usually found on a molder.

For further information you are referred to the J. A. Fay & Egan Co., 226-246 West Front street, Cincinnati, Ohio, who will be pleased to give full particulars.

News Items

The Westinghouse Machine Company reports good progress during recent months in the steam turbine business, despite the general depression existing in the machinery market. While business has been considerably below normal, there have been many encouraging features in all directions of power application. Out of the most important business covering some 20 machines ranging in size up to 10,000 H. P., we find the usual activity in electrical, power and traction work, and a fair demand from various industries, including phosphate, cement and rubber mills, steel car works and oil refineries. Inquiry for exhaust steam turbines is active, and several equipments have been contracted for. Three of the most important orders are the following: Metropolitan Street Railway, Kansas City, 15,000 kw.; Narragansett Electric Lighting Company, Providence, R. I., 7,000 kw.; Capitol Traction Company, Washington, D. C., 3,000 kw.

Electrification of the St. Clair Tunnel

In connection with the inspection of the plant, equipment and appliances of the St. Clair Tunnel, which took place recently, a booklet, giving a technical description of the electrification of this tunnel, has just been issued. This description, written by F. A. Sager, assistant engineer, with Bion J. Arnold, must be of great value to an engineer interested in this line of work.

The Babcock & Wilcox Company has purchased from the Rust Boiler Company its patents and plant, located at Midland, Pa., and will continue the manufacture, at that point, of the Rust water-tube boiler.

THE LATEST CATALOGUES

Electrical Measuring Instruments

Weston Electrical Instrument Co., Newark, N. J.—Circular No. 7, which is written in three parts, the first taking up the new Weston switchboard A.C. ammeters and voltmeters, the second the new portable A.C. ammeters, milli-ammeters and voltmeters, while in the last are described the new eclipse D.C. switchboard instruments (electro-magnetic type).

Boiler Cleaners

The Lagonda Manufacturing Company is distributing an interesting booklet of 24 pages on "The Scale Question." The booklet gives numerous facts about steam power-plant economy and protection, and will interest all who own or have charge of boilers, economizers, condensers, etc.

Among the new Lagonda products described therein is the Weinland Air-Driven Wing-Head Cleaner. This machine is a miniature rotary engine, which goes into the tube and rotates the cleaning head in much the same manner as a turbine does, but is more powerful. The booklet will be sent to all who write to the Lagonda Manufacturing Company, Springfield, Ohio.

Air Compressors

Thos H. Dallet Company, Philadelphia.—Catalogue No. 100, in which are listed belt and steam-driven compressors. It is handsomely illustrated, but does not show the complete line of machines that this company makes.

Motor-Generator Sets

General Electric Company, Schenectady, N. Y.—Bulletin No. 4,633, devoted to the subject of motor-generator sets. Direct current to direct-current sets, alternating current to direct-current sets, or vice versa, varying in capacity from 0.2 kilowatt to 1,500 kilowatts, and alternating current to alternating-current sets between two periodicities, commonly called "frequency changers," are briefly described and illustrated, and illustrations of several installations of such sets are shown.

Automobile Accessories

General Electric Company, Schenectady, N. Y.—Bulletin No. 4629 has just been issued and is devoted to the description of automobile accessories manufactured by that company, which will be of interest to automobile owners. The apparatus briefly described and illustrated in this publication consists of charging panels of various types, automobile instruments, automobile incandescent lamps, motor-generator sets, automobile motors and controllers, battery-charging rheostats, low-tension magnetos, air compressor outfits, etc.

Oil Switches

The Electric Storage Battery Co., Philadelphia, Pa.—Bulletin No. 110, giving a full description of the operation of chloride accumulators, for remote control oil switches.

Gas Engines

The Alamo Manufacturing Company, Hillsdale, Mich.—Catalogue 28, a handsomely illustrated high-class publication describing the gas, gasoline and distillate engines made by this company.

Conveyors

Jeffrey Mfg. Co., Columbus, Ohio.—Catalogue 67D, describing the rubber belt conveyors made by this company, the various illustrations in it showing their application for handling materials of various kinds.

Robins New Conveyor Co., Old Colony Building, Chicago.—Bulletin No. 1, a reprint of a paper on the belt conveyor, by C. Kemble Baldwin, read at the Detroit meeting of the A. S. M. E., June, 1908. The illustrations of the paper very clearly bring out the principles of the mechanism.

Book News

Mars as the Abode of Life

By Percival Lowell. Pp. xvi., 288; 8 plates and 62 illustrations in the text. New York: The Macmillan Company.

Professor Lowell has here gathered together a course of lectures originally delivered at the Lowell Institute in 1906, and afterwards published in the *Century* magazine, but the book is more than a reprint of that interesting matter, since it includes the physical and technical demonstrations from which the arguments and conclusions have been drawn.

Taken as a whole, the work is of especial value as denoting the extent to which physical astronomy has become developed during the last decade, and the manner in which we may use the data gathered upon the surface of the earth to guide us in studying the constitution and conditions of other planets. One of the lessons which such a study may well teach us, is one which mankind has been slow to learn, the fact that man is not necessarily the central feature of the universe, and that physical phenomena must be considered from a far broader viewpoint.

To the engineer, such a study is inspiring for several reasons: it emphasizes the reign of law, far beyond the limitations to which he generally confines it: it shows a planet driven to the last exhaustion of those natural resources which the engineer alone can develop and utilize; and it shows that the termination of habitability of any planet so situated is but a question of time.

..Such a study must necessarily involve speculation, but it is speculation based upon scientific observation, and aided by the most precise apparatus and methods which modern science can furnish, and as the capacity of apparatus increases and the methods themselves are developed, the element of speculation must diminish and the proportion of positive information increase, so that Professor Lowell's study is in itself an encouraging indication of what Tyndall long ago called the scientific use of the imagination.

Power Plants—The Mechanical Engineering of Power Plants

By Frederic Remsen Hutton, E. M., Sc. D. Size 6 x 9 inches. 825 pages. New York: John Wiley & Sons. Price $5.

This is the third edition of a book already well known. The years since the former edition of this book, issued in 1897, have been a period of great and rapid progress in the development of the power plant and all engineering departments contributory thereto. The original edition was modernized here and there, and year by year, but the time arrived with the opening decade of the twentieth century for it to be rewritten entirely. The present edition is the result of such rewriting. The new treatments, specially noteworthy, are those relating to the analysis of the power plant and its diagram, and the separation between the simple and the complex phases of this problem; the treatment of the steam pipe as an element of co-ordinate importance in the plant with the boiler and the engine; the chapters on the auxiliaries as distinguished from the essentials; the steam-turbine chapter, the engine-mechanism chapter, and the establishment of the philosophy of the expansion of the elastic medium as the basis for the design of valve gear, governor, and the condensing and compound engine. This portion is new, and it is believed that it will be, helpful and illuminating. Some data and tables have been introduced, but only sparingly. The author prefers that students should acquire the habit of going to the "Engineer's Pocket Books" for statistical or quantitative information, using this book to give a perspective or setting to make clear the meaning and interpretation of such data and constants as these excellent books are prepared to furnish.

Electric Controlling Devices

AN interesting example of the differentiation of a department of engineering work appears in the manner in which electrical controlling apparatus has grown into a special feature of manufacturing. Probably the earliest department of such appliances was that related to plugs, switches, and the like, for use in connection with telegraphy, but with the enormous development of the electric industry for lighting, power and other work, a great variety of controllers and kindred apparatus has been produced.

One of the reasons for the widely extended use of electric power lies in the ease with which it can be controlled, either near-by or at a distance, and a few examples of the applications of specially designed controllers may here be mentioned.

Thus, in the operation of pumping machinery by electric motors, the possibility of automatic control and regulation appears in a variety of interesting ways. It often occurs that a pump must be placed at a point distant from other machinery, and that the expense of a special attendant becomes a matter for consideration. The use of an electrically driven pump, however, permits the use of special controlling apparatus, including self-starting mechanism, so that the question of distance becomes a matter of minor importance. In other cases the regulation of pumping machinery may be effected in an entirely automatic manner. Thus, by the simple arrangement of a float controller in connection with the tank or reservoir into which the water, or other liquid, is delivered, the pump can be stopped and started automatically as the water-level varies, and the limits of head kept between any desired points. In like manner, the delivery of air or water into closed tanks under pressure may be regulated electrically, the controller in such cases being designed to be operated by pressure instead of a float, and the stopping and starting of the pump or air-compressor definitely controlled between the predetermined pressure limits.

The use of special controllers for electrically-driven machine tools has led to some ingenious developments, and examples of these may be seen in practical use in almost any shop.

Probably one of the most extensive employments of the electric controller appears in the operation of the electric street car, and it has become, in this form, almost as familiar to the layman as the telephone or the electric-light switch.

When the electric motor was applied to the development of the traveling crane, the need for a special form of controller became apparent, the crane itself being a product of the machine shop to which electric motors were applied for the various functions of hoisting, lowering and bridge and trolley travel. The result has been the design of crane controllers particularly adapted for these various movements, placing the entire mechanism wholly under the hand of a single operator with precision and ease, the mechanism being at the same time of the sturdy and effective character necessary in such an important and responsible situation.

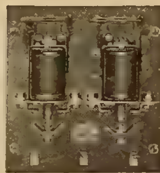
In a similar manner the electric controller has made the electric elevator possible, and has facilitated the introduction of the electric motor into a vast number of applications where it could never have been satisfactorily used had it involved the employment of a skilled electrician for reliable service. With the proper controller, installed under competent supervision, and operated in connection with well-designed motors and connections, it has become practicable to utilize the advantages of the electric current as fully and readily as any of the older methods of power transmission, and in many cases with far greater convenience and efficiency.

CUTLER-HAMMER

Electric Controlling Devices

If you are interested in devices for starting, stopping or controlling the speed of an electric motor, tell us the result you wish to accomplish and we will send particulars of suitable apparatus.

Pump Starters

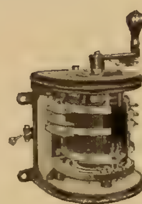


We can furnish promptly complete equipments for motor-driven pumps, comprising self-starter, copper float and float switch for open tank work, or self-starter and gauge type pressure regulator for use in connection with closed tanks or air compressors.

Printing Press Controllers

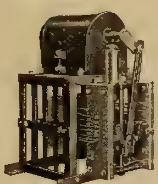
The Cutler-Hammer line of printing press controllers includes controllers for both platen and cylinder presses. We make also controllers for ruling machines, wire stitchers, folders, perforators, and other machines used in printing offices.

Machine Tool Controllers



No fewer than 30 of our Bulletins are devoted to controllers suitable for use with motor-driven machine tools. We can furnish controllers suitable for any class of machine tool, and can ship on short notice.

Elevator Controllers



Ask for Bulletins 51, 52, 53, 54, 56 and 57 covering the most complete line of direct and alternating current elevator controllers on the market. We make self-starters for electric elevators. Belt switches and reversing switches also. Bulletins on request.

Crane Controllers

Cutler-Hammer crane controllers were designed with a full knowledge of the severe service to which this class of apparatus is apt to be subjected. They are of exceptionally rugged construction and all parts subject to wear are made renewable and easy of access. Our illustrated, descriptive booklet on Crane Controllers is free on request.

The Cutler-Hammer Mfg. Co. Milwaukee Wisconsin

New York Office: Hudson Terminal (50 Church St.)
Chicago Office: Monadnock Block
Boston Office: 176 Federal Street

Pittsburgh Office: Farmers' Bank Bldg.
Pacific Coast Agents: Otis & Squires,
111 New Montgomery St., San Francisco, Cal.

Industrial Railways and Industrial Progress

IT has been said that the progress of a nation depends upon the completeness of its transportation facilities, and this is doubtless true to a certain extent. It is undoubtedly true of a workshop or other manufacturing plant, since the cost of a product is, in a large degree, influenced by the amount of handling involved in its production, this element often equaling, and sometimes exceeding, the cost of the actual machining or other manufacturing process.

Formerly the handling of material in the shop was really that which its name implies; it was the manual transport of heavy pieces from one place to another during the various operations to which it had to be subjected. Later there came into service various kinds of mechanical appliances, such as cranes, derricks, chain blocks, and the like, but for a long time these were the only auxiliaries to aid the hands of labourers, the long-distance transport being effected by trucks, teams and animal effort.

When the steam railway came into use the very magnitude of the method seemed to blind men to the fact that it was available for anything but transportation over long distances, and the idea of putting a railway into a shop seemed so foreign to the matter that it was a long time before it occurred to any one. To-day the industrial railway is an established institution, and there are few workshops or manufactories in which it is not employed to a greater or less extent.

The term "industrial railway" includes much more than is always understood, since it covers many things besides a narrow-gauge track laid in and about the buildings of a manufacturing establishment. The modern industrial railway is a carefully thought-out and designed system of transportation, with fully standardized parts, properly constructed curves and switches, and specially designed rolling stock, including cars so arranged as to run with perfect freedom on the standard industrial track for which they have been designed, together with steam or electric locomotives when power propulsion is deemed necessary.

The principle of standardization is now generally accepted as essential in accurate manufacturing of commercial products, and its advantages appear very clearly in connection with the industrial railway. The use of standard curves and turnouts enables extensions and branches to be added to existing installations without difficulty, besides permitting all parts to be kept in stock, insuring uniformity in parts and avoiding the delay otherwise unavoidable.

In the modern development of shop management one of the salient features lies in the determination of the efficiencies of both men and appliances. In considering the efficiency of the industrial railway it is necessary to consider the actual cost, both in labour and in time, in handling material by its aid as compared with the costs of the old-time manual methods. Viewed in this light it will be seen that the shop railway is one of the most efficient devices which can be introduced to raise the efficiency of the whole establishment, both with respect to its own performances and with regard to its influence upon the efficiency of the entire operative force. Anything which diminishes the amount of wholly physical labor and replaces it by mechanical appliances requiring a man to use his brains more and his muscles less, makes for industrial, social, and national development.

Manufacturing News

Carnegie Steel Company

AT the Duquesne plant of the Carnegie Steel Company a large ore-handling bridge has recently been installed by Heyl & about 1,800 feet in length, serving six large blast furnaces. Adjacent to the furnaces are storage bins, under which the larry cars operate to conduct the ore from the bins to the

GENERAL VIEW OF YARDS AND BRIDGE AT DUQUESNE. HEYL & PATTERSON BRIDGE

Patterson, Inc., of Pittsburg, Pa. This is the first bridge of its type built by this company, and possesses a number of interesting features. The bridge spans an ore yard of furnace skips. One supporting leg of the bridge rests on this bin structure, and the other is carried by a concrete wall 26 feet high.

The bridge is of approximately

230 feet span between trucks, and has a cantilever extension at either end of about 65 feet. The iron ore is brought within reach of the bridge by transfer cars, which operate between the car dumper a thousand feet or more from the ore yard and run on tracks carried by the bin structure. These transfer cars discharge their load through an open track onto baffle plates, which form a temporary pile along the bin side of the storage yard. By means of the grab bucket the bridge gathers up the ore and places it in storage or removes it from the storage pile and delivers to transfer cars for distribution into various compartments of the bins, from which the supply for their blast furnaces is drawn as needed. At the end of the bridge farther from the furnaces a "V"-shaped leg furnishes the support, while at the furnace end a single shear leg supports the bridge, as is shown in the accompanying illustration.

Throughout the design of this structure flexibility was sought; this provides for the inequalities in travel of the two ends of the bridge and absorbs shocks and thrusts, due to the quick acceleration of the trolley, without straining the bridge.

The bridge is propelled along its track by two 52 horse-power Westinghouse type "K" crane motors, one on each truck, controlled from the cab. The two controllers for these motors are set adjacent, and are so arranged that a single handle moves either controller separately or both simultaneously. This arrangement allows one end of the bridge to be moved without affecting the other, and on a long travel should one end of the bridge structure get in advance of the other end, the higher-speed motor will be retarded until the slower one overtakes it.

The bucket is a 10-ton Hulett patent excavating bucket, and is operated by two 225 horse-power Westinghouse crane type motors of mill type construction. The bucket, with its load of ore, weighs approximately 50,000 pounds. The trolley traversing mechanism is driven by a 225 horse-power Westinghouse mill type motor, which motor is a duplicate of the two hoisting motors. The two bucket-operating motors are geared together and operate by a single magnetic type controller, providing also for dynamic braking, thus removing a considerble item of wear in the shape of brake blocks from the trolley. The bridge is of very high capacity, having been constructed to handle 600 tons per hour. It has, however, within the last four months far outstripped this amount.

An equipment similar in all respects to this bridge has been supplied to the Youngstown Sheet & Tube Company, Youngstown, Ohio. This machine also is giving very high satisfaction, both as to speed and maintenance.

The length of the Youngstown bridge is approximately 100 feet greater than that of the Carnegie Steel Company's, and the moving gear differs, inasmuch as the bridge is propelled on its tracks by four motors instead of two, the trucks at all four corners being duplicate.

The Philadelphia Bourse

THE city of Philadelphia has long been known as a great industrial and manufacturing centre, and its merchants and business men are among the most active and prosperous in the United States. One of the convincing evidences of this activity appears in the establishment and successful maintenance of the Bourse, an institution of a type well known in Europe, but hardly appreciated in the United States, except in the case of the Philadelphia Bourse, now more than ten years old, and both flourishing and effective in its various lines of work.

The term "bourse," corresponding to the French word for "purse," has more than one meaning, and its relation to the work of the Philadelphia institution is not always under-

stood. The Paris Bourse is the stock exchange, and there is in Paris also a *Bourse de Commerce*, corresponding to the commercial exchanges of various American cities; but the Philadelphia Bourse combines the activities of a number of commercial industries, uniting under one roof nearly all the organized exchanges and wholesale business associations of the city of Philadelphia. The list includes the Board of Trade, Trades League, Commercial Exchange, Maritime Exchange, Grocers' and Importers' Exchange, Drug Exchange, Lumbermen's Exchange, Hardware Merchants' and Manufacturers' Association, Coal Exchange, Oil Trade Club, Paint Club, Carriage and Wagon Builders' Association, Supply and Machinery Dealers' Association, Stationers' Association, Retail Feed and Grain Dealers' Association, Pork Packers' Association, Team Owners' Association, These associations still preserve their individual existence, but under one roof have come closer together, and now act jointly on general matters, securing results more quickly and with less expenditure of effort than in former days, when each acted on its own account. Besides these, the Board of Wardens of the Port of Philadelphia has its offices here, and the Hydrographic Office of the United States Navy is also located in the building.

In the conduct of its work the Philadelphia Bourse includes three distinct departments: the general exchange feature, the offices, and the exhibition department. The first two of these departments are of especial interest to residents of Philadelphia, the exchange feature being well indicated by the list given above, while the office portions of the building are well patronized by members of the various associations for their private business offices, as well as by other active firms and individuals.

The exhibition department, however, is of widespread value, and its advantages should be realized by manufacturers all over the country. This department is intended for the display and sale of all classes of manufactured goods, machinery and raw materials, and affords an opportunity for the development of business in Philadelphia and vicinity which should command the interest of the selling departments of every manufacturing firm which desires to cover this important territory. This exhibition department is in charge of an experienced mechanical engineer, so that it is not necessary for the exhibitor to be in continual attendance, although the office feature of the building renders it possible for a

THE PHILADELPHIA BOURSE

firm desiring personal representation in Philadelphia to have both business office and exhibition space in the same building.

The advantage of having an exhibit in the business centre of the city is manifest, and the opportunity has been embraced by large numbers of manufacturers, not only from Philadelphia, but from all parts of the United States. Among the machinery are found engines built in Iowa, steam pumps from Michigan, bakers' machinery and metal-working machinery from Ohio, fine machine tools from Massachusetts, Connecticut and the other New England States, and it goes without saying that Philadelphia's own manufacturers are well represented. There are various makes of gas, gasoline and oil engines, turbine engines, all of which can be shown in operation, as steam, electric, gas, water or compressed air power can be furnished, beside which there are numerous exhibits of all kinds of mechanical appliances, belting, oils, valves, supplies, and tools of every description.

Any communications relating to the work of the Bourse should be addressed to Mr. Emil P. Albrecht, Secretary, The Bourse, Philadelphia, Pa.

Practical Methods for Developing Industrial Prosperity

THE Railway Business Association, which is composed of concerns all over the country supplying materials and equipments to railroads, and has for its object to restore the purchasing power of transportation companies, has undertaken to persuade boards of trade to pass resolutions looking to the discouragement of anti-railroad agitation.

The propaganda is unique. The motive is described as "enlightened self-interest." The railroads are not able to buy goods, hence the supply plants are shutting down or running part time, and their employees are largely out of work. It is estimated that concerns whose principal customer is railroads or concerns furnishing material to the supply establishments employ, when business is good, about 1,500,000 men. A large proportion are skilled, receiving high wages, and the whole possessing enormous aggregate purchasing power. The association has enrolled members representing a capital of about $500,000,000.

The idea is that these plants want business; these men want work; the tradesmen from whom they buy necessaries and with whom 1,500,000 railroad employees themselves do their shopping are suffering from the shutting off in part of the vast stream of money—nearly $2,500,000,000 in 1907—which the railroads normally pour into the channels of business. Yet all these millions of people have been blithely lambasting railroads by word and applause and vote and law and decree, apparently oblivious to the fact that they were quarreling with their own bread and butter. Anti-railroad agitation, the association contends, by filling investors with apprehension as to the security of railroad investments, has restricted the borrowing power, and hence the purchasing power, of railroads.

This, it is pointed out, is bad for everybody; for it cripples the railroads, preventing them from improving their facilities for handling the traffic of the country or building ahead to create new traffic, and it more or less affects many millions of people who depend directly or indirectly for their livelihood on the money which railroads spend.

"What is the cure?" asks the association. "Stop the agitation," is the answer; and the method is to band together all those directly interested into a movement to make railroad facts better understood and to foster a public opinion favorable to viewing transportation problems without prejudice or passion.

The campaign among business bodies is designed to call the atten-

tion of members of Congress and of the Legislatures to the widespread demand already existing for a commercial breathing spell. Resolutions have been adopted by the Southern Commercial Congress, the New York Board of Trade and Transportation, the Merchants' Association of New York, the Chicago and Indianapolis Boards of Trade, the National Boot and Shoe Manufacturers' Association and many other bodies. The Railway Business Association is sending these to hundreds of commercial organizations, together with an appeal, asking for resolutions urging upon State and national legislators moderation in future legislation affecting railroads, and requesting from legislators and from the Interstate Commerce Commission and State railroad commissions "careful consideration of the contention of the railroads that they are entitled to an adjustment of rates to correspond with present conditions."

The members of the association are writing letters and asking other manufacturers and business men to write letters to their official representatives calling attention to the injury done to local railroad supply industries, and thus to general trade, by the impaired purchasing power of railroads, adding, "It seems to many of us that the laws which compel increased expenditures by railroads should be more carefully scrutinized with reference to what they will cost," and suggesting that the official addressed "favor such an adjustment of transportation rates as will be adequately remunerative to the railroads."

The central office of the association is in the United States Express building, 2 Rector street, New York, and the members are organized in local groups, each handling its own situation. The New York contingent meets once a week, men of large affairs giving much time to discussion of methods. The officers are:

President—George A. Post, New York, president Standard Coupler Co.

Vice-Presidents—H. H. Westinghouse, New York City, vice-president Westinghouse Air Brake Company; O. H. Cutler, New York, president American Brake Shoe & Foundry Company; W. H. Marshall, New York, president American Locomotive Company; E. S. S. Keith, Sagamore, Mass., president Keith Car & Manufacturing Company; O. P. Letchworth, Buffalo, N. Y., president Pratt & Letchworth Company; A. H. Mulliken, Chicago, Ill., president Pettibone-Mulliken Company.

Treasurer—Charles A. Moore, New York City, president Manning, Maxwell & Moore, Inc.

Acting Secretary—G. M. Basford, New York City, assistant to President American Locomotive Company.

Executive Members—W. G. Pearce, Chicago, Ill., vice-president Griffin Wheel Company; W. V. Kelley, Chicago, Ill., president American Steel Foundries; Col. H. G. Prout, Swissvale, Pa., vice-president and general manager Union Switch & Signal Company; J. S. Coffin, Franklin, Pa., president Franklin Railway Supply Company; N. Paul Fenner, Jr., Cincinnati, Ohio, president American Valve & Meter Company; E. L. Adreon, St. Louis, Mo., vice-president American Brake Company; J. H. Schwacke, Philadelphia, Pa., manager and secretary William Sellers & Co., Inc.; A. M. Kittredge, Dayton, Ohio, vice-president Barney & Smith Car Company; John F. Dickson, Houston, Tex., president Dickson Car Wheel Company.

Mr. William Kent (author of the Mechanical Engineers' Pocket Book, and for five years prior to June, 1908, Dean and Professor of Mechanical Engineering in the College of Applied Science, Syracuse University) has removed to Sandusky, Ohio, to take the position of general manager of the Sandusky Foundry & Machine Company, manufacturers of Triplex power pumps, threading machines and specialties in machinery for paper mills.

News Items

The Rockwell Furnace Company, of New York, has been awarded the contract covering the complete furnace equipment for the new locomotive shops of the D., L. & W. R. R. at Scranton, Pa. The furnace equipment consists of thirty-five of the latest type furnaces operated with 300 B. T. U. watergas, which is made in Loomis-Pettibone producers.

These shops will be capable of turning out complete locomotives, and are to be in operation in three months. No pains or expense has been spared to make them up to date, as they embody the latest and most improved machinery and equipment, selected after thoroughly inspecting a large number of railway and industrial plants throughout the country.

In order to afford engineers, architects and others interested in foundation construction an opportunity of familiarizing themselves at first hand with its methods, the Raymond Concrete Pile Company, of New York and Chicago, will give, at the coming Chicago cement show, working demonstrations of its system of making and placing concrete piles. The Raymond system consists of placing a sheet-steel shell in the soil by means of a collapsible steel core, withdrawing the core and thereupon filling the shell, previously subjected to a searching examination, with concrete. The entire operation will be shown at the Raymond Company's booth. A model pile-driver will be employed in the placing of the shells.

At the annual meeting of the stockholders of the Independent Pneumatic Tool Company, held at Jersey City, N. J., the following directors were elected: Messrs. James B. Brady, New York City; W. O. Jacquette, New York City; John P. Hopkins, M. S. Rosenwald, James J. McCarthy, S. Florsheim, John M. Glenn, John D. Hurley, all of Chicago, and John R. Turner, of Jersey City, N. J.

At the annual meeting of the directors just held in Chicago, the following officers were elected: James B. Brady, president, New York City; W. O. Jacquette, first vice-president, New York City; John D. Hurley, second vice-president, Chicago, and A. B. Holmes, secretary and treasurer, Chicago.

The annual report shows that the company is in excellent financial condition, and that during the quarter ending December 31, 1908, forty per cent. more business was transacted than during the same period of 1907.

This company manufactures the "Thor" piston air drills, reversible flue rolling, reaming, tapping and wood-boring machines, pneumatic riveting, chipping, calking and beading hammers, pneumatic saws, motors and other air appliances, and has sufficient orders on its books to keep its plant at Aurora, Ill., running for several months at its full capacity. Its export as well as domestic business is improving, and there is every indication that 1909 will be the banner year since the organization of the company.

Recently the announcement by Colonel Charles Clifton of the formation of the Pierce-Arrow Motor Company, and that it would take over the property, business and good-will of the George N. Pierce Company, was a matter of considerable interest. This action, which in effect amounts to only a change in the official name of this well-known company, appeared at first to some radical. Second thought, however, makes clear that it is merely acquiescence on the company's part in the generally accepted designation of their product, namely, Pierce-Arrow.

The home of the company, of course, remains at Buffalo, and the principal officers of the company are the same, the directors being George H. Birge, president; Charles Clifton, treasurer; Henry May, vice-president; Laurence H. Gardner, secretary, and William B. Hoyt.

THE LATEST CATALOGUES

Self-Winding Clocks

The Standard Electric Time Company, Waterbury, Conn.—Bulletin No. 11. A high-class, beautifully illustrated catalogue, describing self-winding clocks, or regulators, hall clocks, programme clocks, secondary clocks, etc.

Steel Tubes

National Tube Company Pittsburg, Pa.—Book entitled "Shelby Steel Tubes and Their Making," fully illustrated with pictures showing the different processes of manufacturing, such views being special photographs taken for this book. The subject matter is also new, and, all in all, this book should be of decided interest to anybody interested in steel tubes.

Low-Pressure Gauges

The Industrial Instrument Company, Foxboro, Mass.—Bulletin No. 18, covering low-pressure liquid and spring type gauges made by this company.

Alternators

Fort Wayne Electric Works, Fort Wayne, Ind. Bulletin No. 1,109, describing and illustrating the revolving field, engine-driven multiphase alternators manufactured by this company.

Drill Presses

National Separator & Machine Company, 89 State street, Boston, Mass.—A folder illustrating the new 1909 models of cylinder-turret drill presses and their combined oil separators and filters.

Tungsten Lamps for Battery Service

Bulletin No. 4,637, recently issued by the General Electric Company, Schenectady, N. Y., describes various styles and sizes of Tungsten incandescent lamps for battery service. The high efficiency of the Tungsten filament renders it especially suited to the production of an ideal battery lamp, where high efficiency is necessarily a prime requisite. The bulletin illustrates and describes battery lamps, novelty lamps, surgical lamps, lamps for limousine automobile lighting, and various other styles, with miniature bases and bases adapted for use in standard sockets. The bulletin contains also prices of the various types.

D. C. Portable Instruments

Bulletin No. 4,630, recently issued by the same company, contains a description of the Type DP direct-current portable instruments, which have been designed for laboratory and general testing purposes. These instruments are so constructed as to be easily portable, well protected from mechanical injury and from the effect of stray fields. The scales are very legible, and the indications of the pointer are rendered dead-beat. This line of instruments comprises ammeters, voltmeters, mil-ammeters and milli-voltmeters. A full description, together with prices, will be found in the bulletin.

Gas Producers

R. D. Wood & Company, Philadelphia, Pa.—New edition of their catalogue on "Gas Producers and Producer Gas Power Plants." This catalogue has been rewritten and newly illustrated. It deals with producer gas power plants, producers for metallurgical use and with the application of producer gas, amongst which is its successful application to lime-burning.

Condensing Machinery

Dean Bros. Steam Pump Works, Indianapolis, Ind.—Catalogue No. 74, describing independent air pumps, jet and surface condensers, vacuum pumps, combined air and circulating pumps for stationary and marine engines, vacuum pans, distillery cookers and all appliances where a vacuum is necessary.

Book News

Valve Setting

Simple Methods of Setting the Plain Slide Valve, Meyer Cut-off, Corliss and Poppet Types. By Hubert E. Collins. Size 6 x 9 inches. 209 pages. New York: Hill Publishing Company. Price $2.

This book is intended to supply a real demand by supervising, operating, and erecting engineers for a book which gives simple, practical instructions in the setting of valves for all kinds of engines. *Power* has, from time to time, published articles covering the leading types, and this book is based on the material contributed for this series.

The first three chapters of this book are given to the study of the slide-valve movement, as the fundamental principles of all valve design are contained therein. Afterwards a general idea of the Meyer valve movement is given, and then the Corliss.

General rules for finding crank and eccentric centres, which can be applied to any make of reciprocating engine, are given in the fourth chapter. These rules are a valuable aid in valve setting. Careful consideration of the first five chapters will enable a man to grasp the other parts of the book in which special makes of engines are described, and will be highly useful in meeting any problem in valve setting, whether described in detail in this book or not.

Spring Tables

Morrison's Spring Tables, a Handbook for Engineers, Students and Draughtsmen. By Egbert R. Morrison, Jr., Am. Soc. M. E. Size 6 x 9 inches. 84 pages. Published by E. R. Morrison, Morrison & Martin, Sharon, Pa., U. S. A.

This book is divided into three parts, the first of which contains a great variety of formulæ applicable to the various kinds of springs; the second part contains mathematical tables, while the last part contains the spring tables.

Springs fall naturally into two classes, light and heavy: in the case of helical springs called wire and bar; in elliptical springs called sheet and plate. In helical springs the ratio between the diameter of the bar (or similar dimensions in other than circular sections) and the mean diameter of the spring forms the basis of calculation in estimating the various properties of the spring. In elliptical springs the basis of calculation is the ratio between the thickness of the plate and the span or net length of the spring. The properties of heavy springs may be arranged easily under each size of bar or thickness of plate, inasmuch as the number of fundamental ratios for each bar is practically definite. In the present tables, therefore, the writer has arranged the properties of light springs under graduated values of the fundamental ratio, so that the properties of any light spring may be quickly determined from its peculiar ratio. The properties of heavy springs are tabulated under each size bar or plate. The table on rectangular and elliptical sections is designed for use in connection with the other tables on helical springs, the properties of springs made of such sections being easily determined by proportion.

The mathematical tables are included to facilitate the use of the formulas.

Small Tools

Handbook of Small Tools, Comprising Threading Tools, Taps, Dies, Cutters, Drills and Reamers. By Erik Oberg. Size 5½ x 8 inches. 517 pages. New York: John Wiley & Sons. Price $3.

This book has been written to supply a distinct demand for definite data and information on the design and construction of small cutting tools, such as threading tools, taps, dies, milling cutters of all classes, reamers, drills, counterborers, hollow mills, etc. The material has been prepared with special regard to the requirements of the tool-maker,

tool draftsman, foreman, inspector, and superintendent, for specific information relating to tools of the class mentioned. The author also wishes to emphasize the fact that the information given is authentic, and that the book places on record the most modern practice in tool manufacture, the experience gained by him during several years' connection with one of the foremost tool-making firms in the country, the Pratt & Whitney Company, being the basis of the treatise.

An effort has been made to prepare the material for this book so as to give specifically, in plain figures, in tables and in formulas, the desired information. While the book is of a practical character, and intended for the use of practical men, theoretical reasons have not been overlooked, and formulas and deductions of formulas are included wherever advisable. Those who have no interest in the deduction or use of formulas will find the results sought for directly in the tables, without calculations. The portion of Chapter II., devoted to change gearing for the lathe has been prepared with the intention of presenting this matter in as simple a manner as possible, in order to meet the requirements of those whose knowledge of mathematics is limited; hence the rather extended and elementary treatment of the subject.

The Mechanical Appliances of the Metallurgical Industries

A complete description of the machines and apparatus used in chemical and metallurgical processes for chemists, metallurgists, engineers, manufacturers, superintendents and students. By Oskar Nagel, Ph. D. Size, 6 x 9 inches. 307 pages, with 292 illustrations. New York: Published by the author. Price, $2.

In the preface the author states that the aim of this book is to clear up ideas regarding the mechanical appliances used in the chemical and metallurgical industries, and to expose the real importance of the machines used in the various processes and to get rid of the obscurities prevailing at present in these matters.

Therefore, this treatise ought to fill a deeply-felt want, as there is only one book on the market along similar lines, viz., Parnicke's well-known German work.

All the prominent types of machines, such as are of interest to the industrial chemist and metallurgist, have been treated with great detail. In every chapter the best respective machines on the American market have been described, and in this respect the chapters on transportation of gases, liquids and solids, on grinding, mixing, filtering, concentrating, drying, firing, etc., will give considerable enlightenment to readers interested in these subjects.

The chapters on power have been treated from a more general point of view. As to steam power, steam boilers and steam engines are not described in detail, but the requirements of a perfect steam boiler and the subject of the care of boilers have been mainly dwelt upon. However, regarding superheated steam, turbines, and especially gas power, everything that is of interest to the chemical and metallurgical engineer has been said.

Another object of this book is to impart such information as to make buyers of machinery independent of the "talking points" of the salesman. The buyer being familiar with the best types of machines, will easily see if any essential details are lacking in a machine offered to him.

Books Received

A Manual of Underground Surveying. Price, $3. By L. W. Trumbull. New York: Hill Publishing Company.

The Steam Turbine. Price, $4. By J. A. Moyer. New York: John Wiley & Sons.

The Economy Factor in Steam-Power Plants. Price, $3.00. By G. W. Hawkins. New York: Hill Publishing Company.

Mining Methods in Europe. Price, $2.50. By L. W. Mayer. New York: Hill Publishing Company.

Fuel-handling in Manufacturing Establishments

IN nearly every kind of manufacturing the power is generated on the premises, and until the use of gaseous fuel becomes general, this means that there must be a coal pile and a boiler room, and that the fuel must be conveyed from the one place to the other and delivered into the furnaces, where it is to be burned.

Formerly there was but one way of doing this; by main strength. To-day there are a number of scientific methods of handling fuel and removing the resulting ash; the method employed depending upon the magnitude of the plant and upon local conditions.

The great power station has its mechanical conveyors, its overhead bins, its delivery chutes, its cars, towers and operative machinery, designed according to location, and adapted for railway or waterside service, as the case may be. Such equipments form examples of the highest development of the work of the engineer, and have contributed in no small degree to the success of the modern power plant.

The individual manufacturer, however, realizing the impracticability of applying to a boiler room of moderate size the equipment designed for a great power station, often assumes that there is nothing applicable to his needs, and continues to allow the old-fashioned system of wheel-barrow and shovel to be used. Such a method is wasteful in more ways than one. It costs in labor, involving the expenditure of much energy in the actual handling of the fuel, beyond what is really necessary. It also costs by reason of the inefficiency of the appliances, due to the ineffective manner in which the men must work, and the unnecessary number of trips required between coal pile and furnaces. It costs still more because it conduces to imperfect firing; since the extra labor involved in shoveling coal from a heap on the floor often causes the work to be slighted. It also compels the presence of dirt and dust in the boiler room, preventing the effective enforcement of any rules as to cleanliness, thus reducing still further the efficiency of the whole equipment.

The inference that proper coal-handling equipment is not available for the boiler room of moderate size, however, is altogether gratuitous.

The use of such a primitive appliance as a wheelbarrow should not be considered in the firing of boilers in any case, since it is always practicable to employ proper cars, running upon an industrial railway, enabling a ton of coal to be transported from the coal pile to the boiler front with as little effort as is demanded by a barrow full weighing 250 pounds.

The crude method of wheeling coal into the boiler room and dumping it into heaps before each furnace, leaving it to be shoveled in at the discretion of the fireman, may be replaced by the use of cars of proper form and height, in which the coal remains until it is fired, and permitting any furnace to be stoked by bringing the car before the proper door. This method also keeps the floor free from coal and dust, and enables the room to be kept clean.

The same system which simplifies the delivery of the coal is applicable to the removal of ashes, the car remaining in the boiler room until its load of coal has been fired, after which it is used for the removal of a like quantity of ashes, thus permitting the establishment of a systematic handling of the materials with a minimum of labor and expense, and a maximum efficiency.

Thus it will be seen that the same skill and judgment which has been applied to the design of coal-handling equipments for large power plants has also been extended to meet the requirements of motive-power departments of all sizes, the conditions obtaining in each case governing the character and cost of the necessary appliances.

The Transmission of Power.

IT has well been said that nearly all of the great progress which has been made since the beginning of the last century is due to the success of the engineer in the manufacture of power, this giving him the ability to perform tasks otherwise far beyond his physical capacity, and at a rate which could not have been possible under the older conditions.

While this is undoubtedly true, it must be remembered that until modern methods of transmitting power were developed, the extent of its application was very limited. The first steam engines were utilized entirely for pumping water from mines, and a number of years elapsed before it was thought possible to convert the reciprocating motion into a rotative one of sufficient uniformity to permit it to be employed for driving machinery. After Watt had perfected his rotative engine, his successors devoted much of their attention to the transmission of power, and the result was the development of the art of the millwright, as he was termed. A glance at any of the earlier works on mechanical engineering will show the extent to which heavy, slow-moving shafting was employed, the actual transmission from shaft to shaft being made by the use of spur and bevel gearing. Out of such material the general arrangement of the modern factory system was developed by Fairbairn, and with increasing speeds the possibilities of belting and pulleys were revealed, and the consequent extension of power transmission had much to do with the rapid growth of manufacturing.

Methods of driving machines vary according to local conditions, and notwithstanding the value and importance of electric driving for many purposes, machine tools are still extensively driven by belting. Even where electric driving is installed, the so-called "group" system is frequently found preferable to the use of individual electric motors for each machine, the electric motor being employed to drive the line of shafting from which the various machines are belted. This arrangement permits of convenient speed-changes, while at the same time avoiding the installation of extensive systems of line shafting, and it is, like many other things, a satisfactory compromise between extremes.

With well-made equipment, however, the use of shafting, pulleys and belting will long continue to be the standard method for the distribution of power in the machine shop and factory. Much of the loss formerly assumed to be inherent in the method is now well understood to be due to defects which may be largely eliminated. Higher rotative speeds permit the use of lighter shafts and pulleys, while improved hangers, pillow blocks and methods of support enable accurate alignment to be maintained, thus removing one of the principal causes of excessive friction, and materially reducing the amount of power consumed.

The development of these improvements in power transmission has resulted in the elimination of the old-time millwright, the man who visited shop after shop, practically constructing the transmission machinery on the spot, and in his place there is found to-day the great manufactory of power-transmitting machinery, including pulleys of all sizes, made of iron, steel, or wood; as well as standard shafting, specially designed hangers, pillow blocks and bearings; these, and all the auxiliary elements for the transmission and distribution of power being made according to scientifically-designed standards with an accuracy and efficiency utterly impossible under the old methods.

Any consideration of the proper system of power transmission to be installed in any particular case should, therefore, be made not with the old-fashioned ideas in mind, but with full knowledge of modern methods and appliances.

The Development of Elementary Machines.

THE old text books on mechanics had much to say about the various elementary machines, so-called; these including the lever, inclined plane, screw, pulley, wheel and axle, etc. Modern methods rather ignore this classification, rightly perceiving that some of these are only concealed forms of simpler elements, the lever appearing in the pulley and in the wheel and axle, while the screw is simply an inclined plane traced upon a cylindrical instead of a flat surface. At the present time it is more customary to consider what are termed machine elements, these consisting not of simple pieces of mechanism involving elementary movements, but rather of structural parts, such as fastenings, connections, transmission-devices, and similar details, of which the completed machine is necessarily composed.

The term elementary machine to-day is much broader and more general in scope, and includes rather the simpler varieties of tools and appliances as compared with the highly organized machines which represent so much skill and ingenuity in many mechanical operations.

Among these simpler machines may be included the ordinary hoist, which in its simplest form really corresponds to the pulley, in the old list of mechanical power; the single-fixed pulley acting simply to reverse the direction of motion, while the movable pulley, either single or multple, corresponding to the multiplied leverage of the common tackle.

Without detracting in the slightest degree from the simplicity of the old block and tackle, and in fact forming a somewhat simpler device than the multiple rope-hoist, the so-called differential chain-block of Weston came into very general use for the simple operation of hoisting; this apparatus, consisting practically of but two sheaves and an endless run of chain, giving a hoisting leverage attainable otherwise only by a number of parts of rope and of loose pulleys in the common rope tackle, and possessing in addition the invaluable property of sustaining the load at any point without requiring any special mechanism or attention. This remarkable invention has been mentioned as really entitled to a place among the fundamental mechanical powers, and in some respects it is rightly so considered, and its wide use in practical service shows its permanent value as a mechanical appliance.

With the demand for hoisting machines of higher efficiency than is possible with the differential block came successive improvements, these taking the form of the introduction of methods of sustaining the load without impairing the efficiency of action during hoisting, and thus came about the development of the elementary hoisting machine from its primitive type of rope hoist, multiple block-and-tackle, and differential chain block, to the latest forms of chain hoist of maximum efficiency, returning practically 80 per cent. of the effective labour of the operator in the form of useful work.

Various attempts have been made to apply power to the portable hoist, but until the development of the electric motor and the general introduction of electricity in the machine shop, these efforts were attended with but moderate success. To-day the electric hoist forms a most valuable appliance, standing midway between the hand-operated chain block and the large power crane, and indeed it has been found that a very effective method of designing an electric-power traveling crane is to make use of the electric hoist as one of its elements.

The chain block thus forms a most interesting example of the development of a mechanical device in accordance with the laws of evolution, the more highly organized machine appearing as the demand for its service became more insistent.

Manufacturing News

Notable Activity in Gas Engine Building

THE gas engine shops of Allis-Chalmers Company's works, West Allis, near Milwaukee, Wis., present at this time a very busy appearance, due to the shipping out of a large number of power and blowing engines on old orders and the commencement of work upon new.

Among the more notable contracts recently entered into is one with the Pittsburg Plate Glass Company to furnish additional equipment for its plant at Crystal City, Mo., which already contains the famous "Big Reliable" unit of 3,500 KW. capacity, exhibited by Allis-Chalmers Company at the Louisiana Purchase Exposition in St. Louis. The new apparatus consists of two Allis-Chalmers alternating-current generators of 3,000 KW. combined capacity, each driven by a 34-inch by 48-inch horizontal twin-tandem Allis-Chalmers gas engine.

The rotative speed is 107 R.P.M., and the total weight of each unit is about 1,000,000 pounds, the flywheel alone weighing 120,000 pounds. These units have been designed to carry full load at 85 per cent. power factor, and are guaranteed to operate in parallel, delivering 25-cycle, 3-phase current at a terminal pressure of 2,300 volts. Producers will furnish the gas required for the engines.

For the Kokomo, Ind., plant of the same company there are being built three Allis-Chalmers gas engines and generators of the same characteristics as the units named above, but each of half the capacity, or an aggregate of 2,250 KW.

For the Kansas Buff Brick and Manufacturing Company there are being built by Allis-Chalmers Company two horizontal tandem gas engines, one of 500 horse-power and the other of 250 horse-power, to operate on natural gas. They will be installed in one power plant and are to be connected, through friction clutch couplings on the outboard ends of the crank shaft, to a common transmission shaft, on which will be mounted a belt wheel carrying a belt to drive a 150-KW. Allis-Chalmers generator. The 500-horse-power engine will also have a belt from which power is to be transmitted to line shafting in the brick factory. All of the power-transmitting machinery and auxiliary electrical apparatus is to be built in the shops of Allis-Chalmers Company, absolutely eliminating any division of responsibility.

Additional contracts for gas engines and electric generators, at present pending, involve no less than 30,000 horse-power, and indications point to a large increase in the use of prime movers of this type during the current year, their reliability under all conditions of service having been conclusively demonstrated by the engines now in continuous service.

Horizontal Gas Engines

THE Westinghouse Machine Company, at East Pittsburg, records contracts for no less than nine horizontal engines for the past two months, which exemplifies the confidence their users have in this type of power equipment. The most recent contract covers two 750 horsepower tandem units, for the Iola Portland Cement Company, Iola, Kans. They will be installed in an extension to the large cement mill at Iola. It is noteworthy that the Iola Company have had nearly ten years' experience with gas engines in their cement mills, and the operating equipment comprises fourteen engines of vertical and horizontal type, all of Westinghouse construction, some of which have operated for the entire period. The horizontals are of the same type as the new engines, and have established for themselves a record of over a month's continuous operation without closing the throttle, as have also the vertical engines. The new engines will be direct connected to the cement mills as in the previous equipment.

The Salisbury Steel & Iron Company, Herkimer County, N. Y., is installing a new plant with anthracite producers to operate the mill and the mine shafts in the vicinity. The initial equipment will comprise a 600-horse-power horizontal and a 125-horse-power vertical engine, both driving generators which operate at a frequency of 60 cycles. The power house will be located a few hundred feet from the mill, and the shafts about one mile distant. It will also furnish electric power for compressed air and hoisting service to the mines and for concentrating machinery at the mill. An interesting feature at the station was the competition offered by a water-power plant located but six miles distant. Although offering current at a very low rate, it was considered possible to produce power at a still lower figure by a producer gas station. The Salisbury mines produce a high grade of magnetic iron ore.

The Standard Underground Cable Company are also constructing a new mill at Perth Amboy, N. J., and will install a 750 B.H.P. horizontal producer gas electric unit, to furnish electric power to the new wire mill. Gas will be furnished from a plant of Westinghouse anthracite suction producers, yielding gas of about 120 B.t.u. per cubic foot. A certain portion of the producer gas will also be used for heating and annealing operations in the wire mill. This engine will be the first of a new size developed at East Pittsburg, suitable for direct connection to a 500-KW. generator, with reasonable overload capacity. The engine and generator will be solid coupled, operating at a frequency of 60 cycles.

News Items

Robert Thurston Kent has resigned as engineering editor of the *Iron Trade Review*, Cleveland, Ohio, to become managing editor of *Industrial Engineering*, Pittsburg, Pa., a new paper, devoted to mechanical engineering subjects. Mr. Kent has been with the *Iron Trade Review* since 1905, and prior to that time was associate editor of the *Electrical Review*, New York.

Edwin Reynolds, one of the past presidents of the American Society of Mechanical Engineers and for thirty years practical head of the Edward P. Allis Company, now the Allis-Chalmers Company, died at his residence, No. 446 Ivanhoe Place, Milwaukee, Wis., Friday, February 19, at 78 years of age.

Messrs. Burnham, Williams & Co. regret to announce the death, on March 23, 1909, of Mr. William P. Henszey, who had been connected with the Baldwin Locomotive Works since March 7, 1859.

A brief report on the question of suitable regulation of gas service for the City of Chicago has recently been made by D. C. and Wm. B. Jackson. This report is in the form of a paper and should prove of interest wherever questions of this kind come up.

Among the large orders recently taken by the Crocker-Wheeler Company, of Ampere, N. J., is one for two 250-volt generators of 800 KW. and 75 KW. capacity, respectively, for the Emerson Manufacturing Co., Rockford, Ill. Another is for a 300 KW., 125-volt, lighting and power generator for the Oakville Company, Oakville, Conn. The High Standard Steel Company, of Rockaway, N. J., have purchased two 125 KVA., 2,300-volt, 60-cycle, 600 R.P.M. alternators of the coupled type. Two 50 KW. turbo generators have been ordered for the DeLaval Steam Turbine Co., Trenton, N. J.; and several engine type generators of moderate size, among which are a 75 KW. for the Franklin Square House, Boston, and a 50 KW. for the Enterprise Building Company, Fall River, Mass. Eight motors for printing presses have been ordered for Clark & Cox, Denver, Col. Among other orders are one for three 10-horse-power elevator motors for the Ogden Iron & Steel Manufacturing Company, New York city, and a 40-horse-power induction motor for the Stiles & Hart Brick Company, Wier Branch, Mass. The sales of small direct-current motors continue to increase.

The Ohio Society of Mechanical, Electrical and Steam Engineers, organized Nov. 16, 1901, stimulates the presentation and discussion of papers on timely and live questions relating to design, equipment and operation of power plants, at the same time centering the interests of the mechanical and electrical engineers with those of the operating engineers, electricians, as well as owners. For further information apply to F. W. Ballard, president, 601 Canal Road, or to David Gaehr, secretary, Schofield Building, Cleveland, Ohio.

The Rockwell Furnace Company, of 26 Cortlandt Street, New York, announces that they have purchased the factory, drawings, patterns, etc., of the Rockwell Engineering Company, and that the business will hereafter be transacted under the name of Rockwell Furnace Company, incorporated under the laws of the State of New York.

The Cutler-Hammer Mfg. Co., of Milwaukee, makers of electric controlling devices, announce the opening of a district office in Cleveland, Ohio, 1108 Schofield Building. The new office will be in charge of Mr. C. J. Kruse, who comes from the engineering department of the Cutler-Hammer Company, and who is well qualified to advise regarding the proper device to use in any case involving the control of electric motors.

By a unanimous vote, the board of directors of The Merchants' Association of New York, at the meeting held recently, elected the following gentlemen as officers of the association for the ensuing year: President, Henry R. Towne, president Yale & Towne Mfg. Co.; first vice-president, Gustav H. Schwab, of The North German Lloyd Steamship Co.; second vice-president, William A. Marble, V. P. R. & G. Corset Co.; third vice-president, Robert C. Ogden; treasurer, Gustav Vintschger, president Market & Co., Ltd.; secretary, S. C. Mead; counsel, Hon. John W. Griggs.

To fill a vacancy now existing in the board, the directors elected Mr.

Albert Plaut, of Lehn & Fink, who succeeds Mr. William J. Schieffelin, resigned.

Nilson, Miller Company, of Hoboken, N. J., has been incorporated with capital of $25,000. They are located at 1300 Hudson Street, in the shop formerly occupied by W. D. Forbes & Co., and will conduct an engineering and general machine shop business, making a specialty of designing and building, to order, electrical apparatus, gasoline engines, etc., for commercial vehicle, marine and stationary use. Also experimental work and special machinery.

Mr. L. G. Nilson, chief engineer of Strang Gas Electric Car Company, of No. 15 Wall Street, New York city, has been elected president. He will continue as consulting engineer for the Strang Company.

The annual meeting of the stockholders of The Union Switch & Signal Company took place March 9 in the office of the company, Westinghouse Building. Owing to the absence of Mr. George Westinghouse in Europe, Col. H. G. Prout, vice-president of the company, acted as chairman. The financial statement was read to the stockholders and an election for president and directors was held. The following were elected as directors: George Westinghouse, Robert Pitcairn, William McConway, George C. Smith, Thomas Rodd, H. G. Prout, James J. Donnell.

After the meeting, a representative of the company stated that they have at the present time on hand at Swissvale orders for unfilled business amounting to $1,357,000. New contracts for block signaling and other railroad safety devices are now coming in more freely than at any time during the last twelve months. Inquiries for quotation on new business are increasing right along and are spread pretty widely over the entire country.

The purchase of a 750 KW., two-phase, 30-cycle, 440-volt turbo generator set, by the Lyman Mills, of Holyoke, Mass., is but an indication of the satisfaction which electrical apparatus has given in their textile mill. For some years Westinghouse induction motors have been installed throughout the mill to drive the various machines with a total capacity of 900 horse-power, and have given eminent satisfaction. Recently the company decided to install additional generating capacity and purchased a turbine from The Westinghouse Machine Company designed for 150 pounds steam pressure, with 50 degrees superheat and 28 inches vacuum. This turbine unit is now being built at the Westinghouse shops, East Pittsburg.

The United States Geological Survey, in co-operation with the State Geological Survey, has established at the College of Engineering, University of Illinois, Urbana, Illinois, a mine explosion and mine rescue station. The purpose of the station is to interest mine operators and inspectors in the economic value of such modern appliances as the oxygen helmets and resuscitation apparatus as adjuncts to the normal equipment of mines. The station also will concern itself with the training of mine bosses and others in the use of such apparatus. Its service is to be rendered gratuitously, and, so far as possible, to all in Illinois, Indiana, Michigan, West Kentucky, Iowa and Missouri who may desire the benefits thereof.

"The Handy Index," distributed by the publishers, The Handy Index Company, Tribune Building, New York, is a convenient method for dealers and manufacturers of building materials and engineering supplies to reach architects, engineers, builders and contractors in all parts of the United States east of the Mississippi River.

THE LATEST CATALOGUES

Oil Switches

Kelman Electric & Manufacturing Company, Los Angeles, Cal. Bulletin No. 4, describing various types of high voltage oil switches and oil circuit breakers.

Metal Hose

Metallschlauch-Fabrik Pforzheim, vorm. Hch. Witzenmann, Pforzheim, Baden. An interesting and well-illustrated catalogue on flexible metal hose, pointing out the various uses, such as expansion joints, flexible water hose, gas hose and steamhose, to withstand the highest pressures, also its adaptability for casing for electric cables. The sole agents for this company are The American Metal Hose Company, 173-177 Lafayette Street, New York.

Valves and Fittings for Ammonia

Crane Company, Chicago. Catalogue No. 41, superseding the Ammonia Catalogue of 1907, illustrates—with the sole exception of malleable iron screwed fittings—valves and fittings of an entirely new line, that were designed in accordance with the most approved practice.

Tachometers

The Industrial Instrument Company, Foxboro, Mass. Bulletin No. 16, on speed-measuring instruments. The various types of standard revolution counters and tachometers this company imports are well described and illustrated.

Automobiles

The Pierce-Arrow Motor Car Company, Buffalo, N. Y. A handsomely illustrated catalogue showing the fine line of cars manufactured by this company.

Impact Machine

Queen & Co., Philadelphia, Pa. An interesting booklet describing the Landgraf-Turner Alternating Impact Machine. This machine, in view of the new high-grade steels produced by the use of various alloys and the lack of a satisfactory test showing the actual strength of the material under different forms of stress, should fill a long-felt want for just such a machine, and anybody interested in the subject of testing materials will find the perusal of this book of interest.

Blowers

P. H. & F. M. Roots Company, Connersville, Ind. Catalogue No. 32 describing and illustrating the rotary blowers, gas exhausters and pumps made by this company.

Power Transmission

Dodge Manufacturing Company, Mishawaka, Ind. This company has published an interesting catalogue entitled "Power Transmission Engineering." It is quite an extensive book in which everything pertaining to this subject can be found, is profusely illustrated and contains tables of sizes, price lists, etc.

Indicators

The American Steam Gauge & Valve Manufacturing Company, Boston, Mass. Catalogue describing the American Thompson Improved Indicator. It is a well-arranged publication describing the various indicators, such as those made especially for use in connection with steam, ammonia gas and oil. The testing of indicator springs, the Aimsler planimeter and the indicator diagram and its advantages are some of the subjects described.

Lubricants

Joseph Dixon Crucible Company, Jersey City, N. J. Booklet, entitled "Lubricating the Motor," describing the best methods of lubricating all parts of an automobile, motor boat or motor cycle; such as the cylinders, transmissions, bearings, differentials, chains, springs, etc.

Book News

Underground Surveying

A Manual of Underground Surveying. By Loyal Wingate Trumbull, M. E. Size, 6 x 9 inches. 251 pages. New York: Hill Publishing Company. Price $3.

Mr. Trumbull, especially as professor of mining at the University of Wyoming, and earlier as deputy mineral surveyor for Colorado, long felt the need of a suitable text book on mine surveying, based on American practice.

He therefore set about the collection of the material. He has added to his own experience the suggestions and ideas of many prominent engineers who have aided him in the work, and drawn freely upon the published articles of experts as well.

The book deals with both instruments and methods. It discusses the standard instruments fully and carefully. It covers every phase of practice as well, going with the greatest care into the best methods of obtaining the most accurate results in various problems and difficulties which confront the surveyor.

As a whole it is a happy combination of a useful textbook and a valuable surveyor's pocketbook.

Suction Gas Plants

By C. Alfred Smith, B. Sc. (Eng.). Size, 5½ x 8 inches. 198 pages, with 55 illustrations. London: Charles Griffin & Co., Ltd. Philadelphia: J. B. Lippincott Company. Price $1.75.

This book is a publication of a series of three lectures on suction gas plants which was recently given at the East London College. This course was attended by members of the Institution of Marine Engineers, the Association of Engineers-in-Charge, the Junior Institution of Engineers, and students of this and other colleges. It is at the request of many of the engineers who attended the lectures that they are now published.

The first lecture is introductory in character and takes up the details of construction of the suction gas plant. In the second lecture the applications and uses of the suction plant are taken up and some typical plants described. In the last lecture, plants for special purposes are described, and some of the topics treated in this lecture are: Total horse-power of suction gas plants, advantages and disadvantages of the suction gas plant, the effluent from a gas plant, cost of gas production and the gas engine.

The three lectures are followed by five appendices, taken up in the order given: Determination of calorific value of coal gas, determination of calorified value of solid fuels, gas analysis, destruction of tar in the gas producer, method of detecting the presence of carbon monoxide in gas engine exhaust, and, lastly, a note on capital cost of suction gas plants and engines.

It will readily be seen from the contents, as outlined above, that this book must be of interest to any engineer or student partial to the subject of the gas producer and gas engine.

Foundry Practice

A Treatise on Moulding and Casting in their Various Details. By James M. Tate and Melvin O. Stone, M. E. Size, 5 x 7 inches. 234 pages; 112 illustrations. New York: John Wiley & Sons. Price, $2.

Excellent books have been written upon the subject of foundry practice; but, as a rule, most of these have been written with the needs of the experienced moulder in view rather than those of the beginner. It was for this reason that the want of a good text-book has been a serious disadvantage in administering the work in foundry practice at the University of Minnesota. The nomenclature and shop phraseology are not sufficiently elementary for the average beginner to grasp the statement presented, and much time is frequently spent in explaining an author's meaning.

The present little treatise has been

written with a full knowledge of the problems involved and with the object of lessening some of the difficulties which arise in teaching the subject. It is not a complete treatise on the subject, the aim having been to produce a book in which the principles of foundry practice are set forth concisely and clearly. The needs of the engineering student rather than those of the practical foundryman were kept in view.

While the treatment is thus somewhat brief, the subject matter as here presented is intended to cover all ordinary work in foundry practice, including both brass and iron casting. In order to enable the reader and student to become familiar with the names and expressions used by the foundrymen, a glossary of foundry terms has been added.

Alternators

Alternating-Current Machines, being the second volume of Dynamo Electric Machinery, its construction, design and operation. By Samuel Sheldon, A.M., Ph.D., D.Sc., Hobart Mason, B.S., E.E., and Erich Hausmann, B.S., E.E. Size, 5 x 8 inches. 353 pages, with 236 illustrations. New York: D. van Nostrand Company. Price $2.50.

This is the seventh and completely rewritten edition of this book. The scope of the present revision has been determined by the extensive adoption of this volume as a text-book for the use of students on other than electrical courses, and the growing tendency in many Institutions to require more thorough and extended work in electrical subjects from such students. In those cases where insufficient time is available for covering all the ground, portions which the instructor will desire to omit are so treated that the remainder constitutes a co-ordinated treatment. It is also believed that, in the majority of institutions, the book as a whole will be found adapted for the use of students on electrical courses. The manner of presentation is in many parts different from that which would be employed in a book written for engineers, but an extended experience in teaching young men of average attainments has proved it to be effective. As a student seldom gets a thorough understanding of a subject of this character without making numerical computations, problems have been introduced at the conclusion of each chapter.

The Steam Turbine

A Practical and Theoretical Treatise for Engineers and Designers, including a discussion of the gas turbine. By James A. Moyer, S. B., A.M. Size, 6 x 9 inches. 370 pages, with 225 illustrations. New York: John Wiley & Sons. Price, $4.

The order in developing the subject is the reverse of that adopted by most authors. Instead of discussing the intricacies of blading in the beginning of the book, the more simple problems of nozzle design are presented first. A great deal more is now known about nozzles than there was even very few years ago, and many of the conditions affecting the efficiency of nozzles may now be considered well established. Nozzles are also becoming a more important part of all types of turbines. Even the Parsons turbine is now being modified in America and England, so that in many of the latest designs for large sizes nozzles are used in the high-pressure stages. It is coming to be generally recognized that in the future there will probably be no large installations of reciprocating engines for electric services. A few years ago this might have been considered a bold statement, but it is a fact which is now generally, although reluctantly, admitted by manufacturers of reciprocating engines.

In general it should be said that the object of this book is to give in a small volume what engineers and students of engineering want to know about steam turbines. It is intended that it shall be a manual for the practical engineer who is designing, operating, or manufacturing steam turbines rather than a compilation of manufacturers' catalogues, combined with a digest of standard books on thermodynamics and mechanics.

Electricity as a Means of Control

WITH the present development of applications of electricity there is scarcely any department of industry in which it is not employed to a greater or less degree. The first important use for the electric current, after it was found that it could be generated effectively from mechanical power, was in the field of artificial illumination. When it was found that electric motors could be constructed which were commercially practicable, the scope of the art extended to power transmission; this department having been continually extended as the ability to increase transmission-distances became greater and greater. More recently the use of current in electro-chemical operations has produced an ever-widening application, including the development of an entire field of new industries and giving opportunity to capital in fresh methods.

With all these developments there has come a most valuable engineering feature, one which has grown up almost insensibly and which now forms, to a large extent, a separate department of industry, the application of electricity as a means of control, not only of electrical machinery, but also of other kinds of mechanism.

Every one understands that the electric current can be turned on or off by the simple turn of a key, and this convenience forms one of the valuable features of electric lighting. The early street lamps, and their successors, the gas burners, required the services of lamplighters to light and extinguish them, but the modern electric lamps are controlled from the station without inconvenience. With the introduction of the electric motor, especially for street-railway service, it became necessary to provide intermediate controlling features, and the railway controller, in its various forms, came into use. From such applications grew the use of the motor for the operation of machines, such as printing presses, machine tools, cranes, elevators and the like; each of these demanding its own type of controller, and each resulting in the extension of the scope of electric-controller design.

It soon became apparent that the facility for control afforded by the use of electricity could be extended to mechanism operated by other sources of power than the electric current itself. A small electric motor can be used to open and close valves for the passage of steam, water, or gas, and thus, by the use of proper controlling apparatus, the starting and stopping of steam or hydraulic machinery may be effected from almost any distance in a manner formerly not possible.

It is evident that such an extensive series of applications involves a wide experience in this particular department of electrical engineering in order to enable the best method for any special case to be employed.

From the manipulation of a high-speed elevator to the control of the guns in the turret of a battleship; from the automatic starting and stopping of a steam pump to the precise handling of a 100-ton traveling crane, with all the varied and miscellaneous other applications of electrical control, there is opportunity for an almost infinite number of variations in the apparatus by which reliable and accurate control is assured. Thus it has arisen that a special department of electrical industry has grown up, a department enlisting the ingenuity of many investors, and the efforts of many specialists.

Under such circumstances it follows that controlling apparatus produced by the establishments making a specialty of such work must be more effective and reliable than anything which can be made by those who have no such fund of past experience or present facilities upon which to depend, and it is evident that the field for such special work must be an extensive and fertile one.

Fuel Problem in the Power House

IT has been estimated that the actual proportion of fuel cost to total cost in the operation of a modern power house ranges about 40 to 50 per cent. That is, the coal bill is nearly one-half of the entire operating expense, the balance being made up of labour, repairs, interest, depreciation, etc. This means that economy and efficiency in the actual operating work are fully as important as a reduction in the fuel consumption, and that the skill and effort of the engineer should be directed to the minimising of labour, the reduction in time and cost of handling fuel, and to the general improvement of the operative details, as well as to the economical generation and use of the steam.

The general tendency in modern power-house design has been toward the use of larger units, and it has been by the introduction of boilers of great capacity, equipped with automatic stokers, and by the policy of the conversion of the heat energy in the coal into available power upon a very large scale, that the best economies in the generation of steam have been made. A necessary accompaniment of this development is the requirement for the handling of large quantities of fuel and the removal of ashes within comparatively moderate time limits, this involving the substitution of machinery for manual labour, both for stoking and for conveying.

As a result of these conditions there has grown up a complete department of engineering work, involving the design of conveying machinery, storage systems and the general handling of coal and ashes, from the delivery of the fuel to the power house to the departure of the ash and refuse. This means much more than the mere design of conveyors and adjuncts, since the conditions rarely repeat themselves, and each equipment has to be planned especially for the situation.

In nearly every instance the location of a power house is governed by conditions over which the engineer has little or no control, the site being chosen by reason of personal, financial, or other local considerations, the engineer by whom the machinery for fuel-handling is to be designed being often called in after many of the important points bearing upon his work have been fixed beyond possibility of modification. Under such conditions it is evident that the mechanism must be planned to have flexibility and adaptability to a great degree, and to be capable of adaptation to the many and varied circumstances under which it must be used. This means that the entire work of planning, constructing and installing a conveying system for the power house should be in the hands of a specialist, of an engineer who is familiar with the whole problem in all its phases.

A modern power house, then, is not complete unless it is equipped with conveyors, to lift, transport and deliver the coal to proper storage bins; with coal chutes, weighing hoppers, cut-off valves, etc., to deliver the fuel to the automatic stokers; and with ash conveyors, to remove the non-combustible and keep the station continually cleared of ashes and refuse.

With such an equipment, properly designed and constructed, the handling of the fuel may be effected with an efficiency comparable with that of the boilers, engines, dynamos and generating machinery considered as a whole.

Apart from the improvement in mechanical efficiency which results from the installation of modern conveying machinery, it should be considered that the use of such machinery removes most of the laborious work of firing from human effort, and places it where it is effected by inanimate machinery, an end which, from a sociological point of view, is worthy of especial consideration.

The Extension of Rope Driving

IT is probable that the use of round cords of some kind, in the form of the intestines of animals, the fibres of bark, or other natural material, anticipated flat belting as a means of transmitting power and rotary motion. The so-called "fire drill," still used by some savages for originating fire by the rapid alternating rotation of a wooden spindle upon a stationary piece, involves the use of a cord and bow, and the primitive bow lathe, from which the modern highly-organized machine tool has been evolved, is another example of cord or rope driving.

With the development of manufacturing processes, however, the flat leather belt came into very general use, untl, about a generation ago, the possibilities of rope driving for power transmission for certain purposes began to be appreciated.

At first the applications of rope driving were made according to the so-called "English" system, employing a number of independent ropes, each complete in itself and extending once around and between the pulleys, the number of such ropes being governed by the amount of power to be transmitted. This system was usually limited to the transmission from the engine to the jack shaft, whence the motion was distributed through the establishment by belting and shafting.

The limitations of this method led to the development of the "American" system, employing a rope of comparatively small diameter, passing around the grooved sheaves a number of times, and controlled in direction and tension by a suitable idler pulley and tension carriage, the rope being in one endless piece, involving the well-known mechanical principle of reduplication, with the consequent ability to produce any required grip upon the sheaves.

This development extended the capacity of rope driving to an almost indefinite extent, obviating the necessity for the precise alignment of the shafting, so essential for good results with belting, and permitting transmission to be made under conditions previously impracticable.

Thus, by using the American system of rope driving, it is possible to transmit large powers from one shaft to another with such a short distance between centres than it would be impossible to get satisfactory results with belting. If the shafts are so situated that it is inconvenient to place them parallel with each other, it is easy to use rope driving, but very inconvenient to employ belting, while for shafts at any angle the objectionable quarter-turn belt may be entirely eliminated and a rope system devised which will meet any conditions which may present themselves.

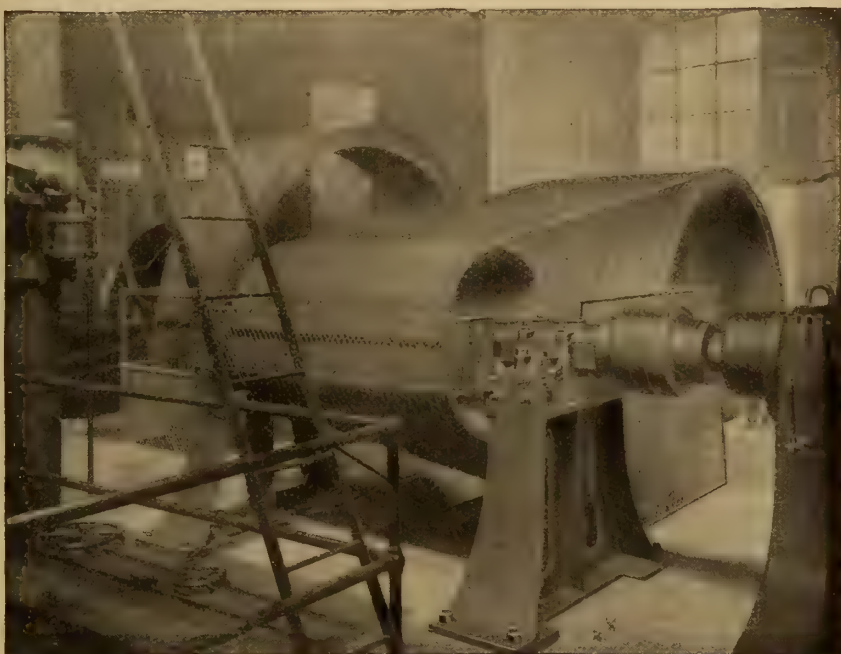
These capabilities of rope transmission have led to the mistake in some instances of assuming that a satisfactory transmission can be arranged by any one, and that no especial experience or previous knowledge of the subject is required. As a matter of fact, there are many elements which unite to make up a wholly successful transmission system, especially in cases which include angular shafting relations, close centres and similar features, and it is most desirable that transmissions of such types, or indeed of any kind in which entire success from the start is desired, should be planned by specialists in this department of engineering.

A large part of the success of any form of transmission mechanism lies in the exercise of correct judgment in the choice of the system beforehand.

For many locations, belting is to be preferred, while in other instances independent electric driving offers exceptionable advantages, but in very many cases the adaptability of rope driving can be perceived only by the experienced engineer, having in mind previous precedents, and familiar with methods under which success has already been attained.

DODGE

Rope Driving



DODGE SHORT-CENTER ROPE DRIVE TO 250 K. W. GENERATOR

The Dodge American System has a very wide range of adaptability in the transmission and distribution of power. Long or short centers. Large or small units. In or out-doors. At any angle. In any direction. Over or around obstacles. Noiseless, efficient, positive, yet having sufficient elasticity to absorb shocks from fluctuating loads. **Twenty-five years of knowing how** insures economy, efficiency and satisfaction in every **Dodge Designed** drive. Write for book, "Rope Driving," 9 x 12 in. now on press.

DODGE MANUFACTURING COMPANY

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Wastes of Human Energy

WE used formerly to hear much about the "dignity of labour;" this phrase apparently being intended to convey the idea that the brutal effort of human muscles had something about it which was in itself creditable, notwithstanding the fact that it is generally believed that the burden of hard physical labor was imposed upon mankind as a punishment. At the present time, however, it is beginning to be realized that there is no more creditable performance or undertaking than that which relieves man from heavy muscular effort, and that the inventor or engineer who devises means for relieving men from excessively hard work is really a benefactor of the human race.

The visitor to the ruins of the Old World gazes upon the pyramids and the remains of the Egyptian temples and considers the enormous waste of labor and life represented by the raising of those huge structures; and possibly he may imagine within himself the vastly different manner in which such work would be done to-day, utilizing modern appliances for moving and raising bulky and heavy masses. Probably there is no one feature which distinguishes modern civilization from the ancient more than the extent to which mechanical appliances have assumed the burden formerly borne by the workman, and the completeness with which human effort has been replaced by machinery.

In the old days men were cheap, not only as regards wages, but even in respect of their very existence, and if the immensity of an undertaking used up the lives of many workmen there were plenty more to replace them, and the waste was considered insignificant. Modern civilization has changed all that, and it is one of the triumphs of the engineer that he has taken the burden of heavy labour from the back of the man and placed it in the tireless grasp of the levers of mechanism; raising human effort, step by step, from the bonds of slavery, compulsory or self-imposed.

To-day the effort of the engineer has yet a further problem to solve. He has taken the burden from human muscle, but, in many instances, he has done this with but little gain in actual efficiency. With the increasing value of human energy it has become more and more essential that it be utilized to the highest degree, and, with the transfer of effort from the hand to the head, it has become increasingly important that the efficiency of the machine which is to save the man shall be increased. The older hoists had efficiencies well below fifty per cent., and, indeed, in most cases this was the fundamental mechanical principle upon which they were designed, in order that the load might not have so great an efficiency in descent as to overcome the resistance by which it must be supported.

The modern hoist cannot afford to waste so large a proportion of the human energy by which it is operated, and with the modern demand for high ultimate efficiency, the resultant of the several efficiencies of successive men and machines, each device must have the maximum efficiency possible, otherwise the final result will be beneath acceptance.

Probably this question has been met in the design of the modern high-efficiency chain block more fully than in any other simple machine in existence. When we consider that the most highly perfected steam engine does not reach an efficiency of 20 per cent., that the highly-praised combustion engine is considered remarkable when its efficiency exceeds 30 per cent., and that the efficiencies of various tools are well represented by these performances, we may well feel that the engineer by whom the efficiency of the triplex chain block was made to attain 80 per cent. is entitled to be ranked among the benefactors of mankind.